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Ordovician Graptolites from the Cliefden Caves Area, Mandurama, N.S.W., with a Re-appraisal of their Stratigraphic Significance

By H. T. Moors

Geology Department, University of Melbourne, Parkville, Victoria 3052

Abstract

Graptolites from an area approximately 18 miles NE. of Cowra, N.S.W., near the Cliefden Caves, were examined. Seventeen species and subspecies are described, of which *Dicellograptus minutus, Climacograptus fusiformis* and *Orthograptus calcaratus clavensis* are new.

On the basis of this collection the age of the sediments in this area can be more precisely determined. The sediments are shown to be Eastonian (Upper Caradoc), and hence younger than previously determined by Sherrard (1954), who designated this as the type area for *Nemagraptus pertenuis* or Gisbornian (Lower Caradoc).

Introduction

The area studied is approximately that delineated by N. C. Stevens (1952, Pl. 3) as the 'Cliefden Caves District', which is centred around the Cliefden Caves, approximately 18 miles NE. of Cowra, N.S.W. The Ordovician sequence here consists of at least eight thousand feet of intercalated marine sediments and igneous material (mainly effusive).

From the investigations of the early workers (Trickett 1908, Booker 1950) it was assumed that the strata which comprise most of the area were of Silurian age. Stevens made a collection of graptolites with which Mrs K. Sherrard dated the beds as the lowest part of the Upper Ordovician (Stevens 1952). With the passage of time, this dating has become widely accepted.

In conjunction with an examination of the prolific shelly fauna of the district, the author collected some graptolites to confirm the accepted age. A number of new forms were found, with a more restricted range than those identified by Sherrard, indicating that the age was younger than previously thought. The work herein is a slightly modified portion of a thesis submitted to the University of Sydney as partial requirement for the degree of Master of Science.

Stratigraphy

The Ordovician rocks of the area have been divided into four Formations, each typifying a certain environment and phase of deposition. These are the Walli Andesite (oldest), the Cliefden Caves Limestone, the Mallongulli Formation and the Angullong Tuff (Stevens 1952, Moors 1966).

During most of the Ordovician the area was apparently on a submarine high, the Molong Geanticline, within the Lachlan Geosyncline. During the time of formation of the Walli Andesite this high seems to have been mostly submerged: little eroded material was available, and the stratigraphic sequence was built up by igneous activity, principally submarine flows. When igneous activity ceased

the water over the high was shallow enough to support a large and varied fauna (Moors 1966), and limestone began to be deposited (Cliefden Caves Limestone). Finally, emergence occurred and a terrigenous component mixed with the limestone to form the localized and very characteristic sediments of the Mallongulli Formation. Later, igneous activity was renewed in the area with more lava flows, until shallow water conditions were generally established. Large numbers of emergent areas supplied both erosive and eruptive material, conglomerates and tuffs, etc., which make up the Angullong Tuff.

This relationship of lithology to environment (that is, position in relation to the submarine high) is stressed because workers to the east of this area have assessed differently the ages of these same Formations and their boundaries. Fig. 5 of Smith 1966 (p. 256-257) shows how lithological boundaries (and hence formation boundaries) can be time-transgressive, and demonstrates his conception of the relationship of the Cliefden Caves area with his adjoining eastern area. Smith has indubitable Darriwil graptolites in the Mallongulli Formation, and a complete absence of the Cliefden Caves Limestone immediately to the east. Some preliminary investigations by the present author also indicate that the Mallongulli Formation-Angullong Tuff boundary in Smith's area is older than in the Cliefden Caves area. However, since this paper restricts itself to the immediate locality around Sherrard's defined type area for the Zone of *Nemagraptus pertenuis*, the variation in formation ages can be neglected here.

The Mallongulli Formation provides almost all the graptolites described below. It is very rich throughout in graptolites, but in only a few localities is their state of preservation suitable for study (localities Co/I/137-139 and 131). Localities are designated by special University of Sydney numbers. These are equated to military grid numbers in Table 1.

TABLE 1

Table correlating Sydney University Geology Department locality numbers with grid references on the Canowindra 1" = mile Military Map

S.U. Numbers	Grid Reference
Co/I/131	801-421
Co/I/137	841-470
Co/I/138	841-467
Co/I/139	845-466
Co/I/144	840-501

The Age and Graptolites of the Mallongulli Formation

When Sherrard (1954, p. 80) erected the Cliefden Caves area as the type area for the Zone of *Nemagraptus pertenuis*, she supported her assumption by a collection of graptolites identified as:

Isograptus (Didymograptus) caduceus var. *tenuis* (rare)
Nemograptus explanatus pertenuis (common)
Climacograptus cf. *antiquus* (rare)
Dicellograptus cf. *divaricatus*
Glyptograptus teretiusculus
Retiograptus geinitzianus
Thamnograptus sp.

However, it will be noted that two of her identifications are tentative, only comparisons with forms, and examination of the other graptolites reveals mis-

identifications. Sherrard's specimens of *Isograptus* and *Nemagraptus* (p. 259, 261) are here considered to be dicellograptids and her *Retiograptus* specimens (p. 278) to be *Orthoretiolites*. Sherrard's glyptograptids were not examined, but specimens from her localities appear to be *G. tenuissimus*. Because of its long range the dendroid *Thamnograptus*, in generic identification only, may be discounted as an age index in subdivisions of this small size.

From a second locality at the base of the Mallongulli Formation (Co/I/139) and hence slightly older than the first locality, Sherrard again (p. 80) identified *Thamnograptus* (which may be again discounted), *Dicellograptus* cf. *divaricatus*, *Climacograptus* cf. *antiquus* and *Glyptograptus teretiusculus* which may probably be again equated to the same forms as at the first locality, as well as *Dicranograptus ziczac* var. *minimus*, which has a restricted Gisbornian age. The author has not found *D. ziczac* var. *minimus* at this locality, but only specimens identified as *D. kirki*, with an Upper Eastonian range, which could have been mistaken for it. As Sherrard did not describe *D. ziczac* in her paper, nor *Climacograptus* cf. *antiquus*, nor *Dicellograptus* cf. *divaricatus*, these correlations must remain speculative.

At a third locality in the Mallongulli Formation, Sherrard again does not describe but merely lists the forms present (Adamson & Trueman 1962, p. 10). Here she has two forms of long range, *Cryptograptus tricornis* and *Climacograptus scharenbergi* plus the shorter ranged *Dicellograptus angulatus*, Gisbornian range. This is the range of *D. angulatus* assigned by its authors, Elles & Wood. However, Ross & Berry (1964) give it a much higher range in the Basin Ranges of North America.

Summarizing Sherrard's identifications and excluding her *Isograptus* and *Nemagraptus*, we find that her assemblages could have a possible range of lower Gisbornian to mid-Eastonian (see Table 2a) and there is no definite criterion for restricting the assemblages to any of these three zones.

Table 2b shows the position of the fauna as identified by the present author. From the spread of the ranges we can give the assemblage only an upper Eastonian age (Elles & Wood's Zone 12, the Zone of *Dicranograptus clingani*, or Thomas's Australian equivalent Zone of *Dicranograptus hians*).

For purposes of geological dating the most critical parts of the fauna are *Climacograptus tubuliferus*, *Dicranograptus* cf. *kirki* and *Diplograptus ingens wellingtonensis*. The *Climacograptus tubuliferus* has been positively identified: a large number of individuals were collected in all stages of development and compared favourably with other Australian and British specimens. This is a very useful fossil, since it has been found to have a restricted range, entirely in the Zone of *Dicranograptus clingani* in Australia. Some doubt exists as to the exact identification of *Dicranograptus kirki* (see p. 262) but whatever form is chosen it would have very nearly the same range and would not alter the age of the strata. The identification of *Diplograptus ingens wellingtonensis* may also be questioned as only two poorly preserved specimens were found. However, after comparison of these specimens with type material in the Victorian Mines Department the author feels confident of the identifications.

Apart from these independent species, we find that the total assemblage bears an Eastonian rather than a Gisbornian aspect. The large diplograptids of the Gisbornian are absent; the glyptograptids are represented by the one small form rather than the many larger forms allied to *G. teretiusculus* of the Gisbornian; the orthograpti do contain subspecies of *O. calcaratus* but they are smallish forms, and likewise *O. truncatus* is represented by small subspecies; and the *Mesograptus*

TABLE 2

The ranges are extremes for the species compiled from Thomas, 1960 and Rose and Berry, 1963.

(a) Sherrard's Identifications, 1954, 62.

Elles and Wood Subdivisions	7	8	9	10	11	12	13	14,15
British Subdivisions	Llan-virn	Llandeilo	Caradoc					Ashgill
Australian Subdivisions	Darriwil		Gisborne		Eastonian		Bolindian	
Iso. caduceus tenuis								
Nema. exclanatus pertenuis								
Dicello. angulatus								
" divaricatus								
Dicrano. zic zac minimus								
Climaco. antiquus								
" scharenbergi								
Glypto. teretiusculus								
Retio. geinitzianus								
Crypto. tricornis								
(b) Author's Identification								
Lepto. eastonensis								
Dicello. elegans								
" caduceus								
Dicrano. kirki								
Climaco. tubuliferus								
" supernus								
" bicornis								
" tridentatus								
Diplo. ingens wellingtonensis								
Ortho. truncatus pauperatus								
" calcaratus clavensis								
" whitfieldi								
" apiculatus								
Glypto. tenuissimus								
Orthoret. hami								
Crypto. tricornis								

present is the small *Diplograptus ingens wellingtonensis*. The abundant *Climacograptus bicornis* of the Gisbornian is absent and instead we find larger numbers, both in species and individuals, of dicellograpti with complicated thecae, and abundant leptograpti, represented by narrow forms. The dicranograpti are also represented by a species, *D. kirki*, with complicated thecae.

Thomas (1960, p. 12) states of the Gisbornian '. . . the assemblage in these

horizons is readily recognizable. *Glyptograptus teretiusculus* is still abundant, together with larger forms of orthograpti such as the varieties of *O. calcaratus* and varieties of *O. truncatus* and *O. whitfieldi*. Climacograpti have also become abundant and these are represented by forms allied to *C. antiquus* and *C. bicornis*.' With this he contrasts the Eastonian as 'characterized by the large diplograpti' (yet not so large as those of the Gisbornian), 'including *Diplograptus ingens*, dicranograpti of the type of *D. hians* . . . and the leptograpti present are close to *L. flaccidus*'. Thomas further states '. . . Typical of this zone are *Dicellograptus morrisi, D. elegans, D. caduceus, Climacograptus caudatus, C. tubuliferus, Orthograptus calcaratus, O. truncatus, Leptograptus flaccidus* and *L. eastonensis*.' Some of these are forms which have been identified from the area and many of the other forms of the area show equivalent degrees of evolution.

Having assigned the fauna to the Zone of *Dicranograptus hians*, it is necessary to extend the known ranges of some of the forms present. Most of the extensions are small and often lie in the range of the form in one country but not in another. The zonal range tables of Ross & Berry (1963) are very helpful in equating the ranges of some graptolites in Britain, Australia and the Basin Ranges of western U.S.A., and give examples of some of the extensions of some forms from country to country. In the climacograptids we find that the range of *C. tridentatus* should be lowered a little into the next zone and this would not present problems. The identification of *C. supernus* is not regarded as definite; it is only stated that the form here described bears some relationship to *C. supernus*. Thus, though we expect it to have a similar range, it is not surprising to find that this form has a slightly earlier age. *Orthoretiolites hami* and *Orthograptus whitfieldi* likewise are only comparisons and it is not too difficult to extend their ranges by the small amounts necessary. It is not so easy to explain the large, full zone extension of the range of *Orthograptus apiculatus*.

The Age and Graptolites of the Angullong Tuff

Stevens (1952) gives two graptolite localities within this formation but could identify the forms present only as being of the diplograptid type. Adamson & Trueman (1962, p. 10) gave some specimens to Mrs Sherrard who identified them as *Orthograptus vulgatus* and stated that they belonged to a higher zone than her collection from the Mallongulli Formation. Unfortunately, Adamson & Trueman designated the locality as BP 5 in their paper and locate it on their map only as 'Por. 13, Ph. Carlton'. This portion contains all the upper three Ordovician Formations, but it seems likely that the specimens did come from the Angullong Tuff. The author tried to relocate these localities but failed to do so. However, three other localities have been found (Co/I/144 to 146 inclusive) though these contained few individuals and few varieties.

Locality Co/I/144 provided the largest collection and contains a new dicellograptid, *D. minutus*, as well as the new variety *Orthograptus calcaratus*, other orthograptids of the *truncatus* group and species of *Glyptograptus* and *Climacograptus*. This assemblage is not particularly conclusive but does indicate a Bolindian age. The dicellograptid as a new species does not shed much light on the age but the orthograptids appear to have affinities to Upper Ordovician-Lower Silurian forms and the *Glyptograptus* has a long narrow shape with markedly alternating thecae suggestive of a Silurian species.

From the other localities only poorly preserved diplograptids were collected which, from their size, were probably related to the *Orthograptus calcaratus* group.

Systematic Descriptions

Order Graptoloidea Lapworth 1875

Family Leptograptidae Lapworth 1879

Genus **Leptograptus** Lapworth 1873

Leptograptus eastonensis Keble & Harris 1925

(Fig. 1a-d)

Leptograptus eastonensis Keble & Harris 1925, p. 514-515; Pl. 69, fig. 1a-d, text-fig. 147.

Diagnosis: This is an unusually thin leptograptid, differing from most in the proximal region where the initial angle of divergence of the first thecae is about 130°. The thecae are simple, straight, elongate tubes only complicated by apertural spines in the first few thecae; they number 9-10 per cm in mature portions.

Description: The rhabdosome is bilaterally symmetrical about the sicula with very slender stipes, commencing with a width of 0·3 mm and reaching 0·6 mm only in some of the more distal fragments. The first thecae grow downwards at an angle of divergence of 130°, but the stipes quickly become horizontal or even slightly reflexed and stay so for the rest of their length. The curvature of the stipes is mostly confined to the proximal region, most of the stipe being straight. Most of the specimens have short stipes but some fragments indicate lengths over 5 cm indicating that the shorter ones could be broken or immature individuals. The thecae are spaced at about 9 to 10 per cm for most of the stipe, but proximally a maximum of 11 per cm may be reached (throughout this paper the number of thecae per centimetre are calculated from the number in the longest available or suitable length of stipe, if the number cannot be counted for a full centimetre).

The thecae are very simple, being long, narrow, straight tubes with the only modification a slight denticle in the early thecae. The first two thecae on each stipe may show a slight denticle and this may be carried on to the third or fourth, but it at all times remains inconspicuous. Proximally, the thecae are a little over 1 mm in length and have a width slightly less than 0·2 mm, giving a length-breadth ratio of five or six. Further away from the sicula the thecae become larger with a length of up to 1·5 mm but the width hardly increases (i.e. the length-breadth ratio increases). A slight change in the inclination and overlap of the thecae takes place, increasing the values distally. Though the changes are small, the inclination being always about 10° and the overlap one quarter, they offset the increased length of thecae and the theeal count remains almost constant at 10 thecae per cm.

The sicula is nearly cylindrical in shape and merges completely into the nema. It may have a width of up to 0·25 mm and a length of over 3 mm. The initial thecae and crossing canal are high, often exposing the bare sicula below them.

Horizon and Localities: This species has been found only in the Mallongulli Formation at localities Co/I/137 and 139. This distribution is probably more apparent than real as the delicate stipes require fine preservation.

Discussion: The narrow morphological ranges of components within the genus and the generally poor preservation have made identification difficult. As well, the long thin nature of the stipes caused many of them to be broken before burial, giving the appearance of a dwarf fauna.

It is probably this form which had been misidentified as *L. validus* (Sherrard 1954). It can be readily separated from *L. validus* by its more slender appearance and generally smaller size.

Keble & Harris (1925) first erected the species as a distinct form, but Thomas (1960) apparently had doubts about its individuality. Twice he refers to it as *L. flaccidus* var. *eastonensis,* but once also as *L. eastonensis.* There is obviously some error here, but it appears that Thomas may have regarded the form *eastonensis* to be of subspecific importance only, preferring to place it in the species *flaccidus.* The long tapering sicula and tenuity of stipes shows the strong affinities to *L. flaccidus* but, as pointed out by Keble & Harris, the proximal region is quite different in the angle of divergence, etc. I would rather agree with Keble & Harris that the form is distinctive enough to have specific standing.

The Mt. Easton fauna collected by Keble & Harris, in the museum of the Victorian Department of Mines, appears to be identical to the Cliefden forms and showed almost exactly the same variations.

Family DICRANOGRAPTIDAE Lapworth 1873

Genus **Dicellograptus** Hopkinson 1871

Dicellograptus elegans Carruthers 1868
(Fig. 2d-g)

Dicellograptus elegans Elles & Wood 1904, p. 159-160, fig. 100a-c; Pl. 23, fig. 2a-e.
Dicellograptus elegans Ruedemann 1947, p. 380-81; Pl. 63, fig. 1.
Isograptus caduceus var. *tenuis* Sherrard 1954, p. 94; Pl. 10, fig. 5.

DIAGNOSIS: The overall shape of the rhabdosome with its short sub-parallel proximal and distal portions and diverging intermediate portion is very characteristic. Thecae elongated, introverted and introtorted, with spines, if present, restricted to early thecae.

DESCRIPTION: The rhabdosome begins at an open, square axil. This openness is caused by the initial thecae growing at right angles to the sicula for most of their length, only turning upwards at their extremities. From this base the stipes extend for about 1 cm in a sub-parallel position before each branch takes a sharp turn outwards to decrease the angle of divergence. The stipes may then either gradually revert to their sub-parallel orientation or, after a short period of divergence, again sharply flex back to their original angle of divergence.

The stipes commence with a width of about 0·4 mm and widen very slowly, reaching only a little over 0·5 mm distally. There are some more robust forms; these also show very little widening and may reach a maximum width of only 0·8 mm. The stipes show a great deal of variation in length but this is probably due to breakage before burial, and a more reasonable length for a mature individual would be between 2 and 3 cm. The initial angle of divergence of the stipes is commonly 270° to 290°; however, because of their slender nature or the particular conditions of burial, the angle of divergence may vary considerably. This slenderness also causes the stipe to be deformed, somewhat masking the characteristic shape. The more slender specimens appear to have fewer thecae per given length of stipe, having thecal counts of only 9 to 10 per cm as against 10 to 12 in the broader forms. In all cases the count increases somewhat towards the sicula.

The initial thecae diverge at an angle slightly less than 180° and are quite straight, except for their very distal end where they bend sharply and have a prominent mesial spine. The second thecae begin parallel to the first, but once past the aperture of the first take a sharp turn upward to start the rest of the stipes in their final direction. The second thecae show definite sigmoidal curvature as do all subsequent thecae. Overlap is small and the aperture lies in a sharp, deep

excavation, approximately half the width of the stipe. The free ventral wall is straight for the greater part, but the distal third is curved as the thecal aperture is introtorted. At the point of sigmoidal curvature of the thecae a mesial spine may be given off; it is usually confined to the first two or three thecae and may reach a length of over 1 mm. The thecae have a length of from 1·0 to 1·2 mm and a width of 0·3 to 0·4 mm. The angle of inclination is always low at about 10°.

The sicula in all cases appeared to be broken off: as the remaining fractions are quite stout it would probably be fairly long. The fragments remaining had a width of 0·25 to 0·35 mm. The aperture bears a short virgella.

Material: The species was abundant but most of the specimens poorly preserved in a leached rock. Some better specimens in fresh rock showing finer details were found.

Horizon and Localities: The species is found at a number of localities but appears to be common only at the base of the Mallongulli Formation.

Discussion: This is presumably the dicellograptid described from the area as *D.* cf. *divaricatus* (Sherrard 1954). However, it differs from this species in a number of points. The most significant difference is in the axil, which is wide and square in *D. elegans* but small and angular in *D. divaricatus*. The stipes also do not widen markedly as they do in *D. divaricatus*.

With the variation in the width of stipes is a variation in the dimensions of the thecae; the longer they are the narrower they become, though the overall shapes are identical. Though in all cases the first thecae have prominent spines, only the broader forms appear to keep these for any length of stipe, the narrow forms having only two or occasionally three spinose thecae.

From the synonomy it may be seen that the author disagrees with the identification of *Isograptus caduceus tenuis* from the area, believing it to be in fact *D. elegans*. The specimen in question (Sherrard 1954, Pl. 10, fig. 5) and Fig. 2, this paper, has been kindly lent by Mrs Sherrard. It came from the Malongulli Formation at Licking Hole Creek (Grid Ref. 818, 450) but a search of this locality failed to locate any more.

Sherrard described the thecae of this specimen as 'almost conical, 0·5 mm wide at aperture but 0·25 mm initially . . . aperture everted with a strong denticle', which is a reasonable description of the thecae of the 'left' stipe, but an examination of the 'right' one shows thecae with definite sigmoidal character. It is obvious that preservational deformation can only simplify the shape and a dicellograptid theca on a twisted stipe is here postulated to explain the strange profile. On the undeformed 'right' stipe Sherrard's aperture can be seen as the curved free ventral wall of the theca, and her denticle as a mesial spine, the aperture being in fact simple, introtorted and introverted rather than 'everted with a strong denticle'. The width of the aperture is not 0·5 mm on this interpretation but in fact much like the width of the base of the thecae, 0·2 mm.

The most characteristic feature, and that which caused Carruthers to choose the specific name *elegans,* is the shape of the rhabdosome. Elles & Wood (1904, p. 159) describe it: 'The stipes are thus at first straight, next concavely and ultimately convexly curved, though the degree of convexity varies in different individuals, but the proximal double curvature is eminently characteristic of the species.' Some double curvature of the stipes is typical of all the specimens collected here.

Dicellograptus minutus sp. nov.

(Fig. 2a-c)

TYPES: Holotype 9646; paratypes 9647 and 9648.

DIAGNOSIS: This species is characterized by an extremely small size and proportionate slenderness. The largest specimen has stipes less than 7·5 mm in length with a maximum width of 0·25 mm. The thecal count is very high with 15 or 16 thecae per cm.

DESCRIPTION: The rhabdosome is extremely minute but of typical dicellograptid form. The axil is square and open. The first thecae instead of diverging at an angle of 180° do so at a smaller angle making the sicula region distinctive. After this the axillary angle is always large, between 330° and 320°, and as the stipes themselves are straight this value does not vary away from the sicula. The branches are slender, ranging in width from only 0·2 mm to 0·25 mm, and appear almost parallel-sided for their whole length. The thecal count is very high, an extrapolated value giving 15 or 16 per cm distally and probably higher close to the sicula. The shape of the stipe is also characterized by relatively large spines on the first thecae of each stipe.

The first thecae diverge at an angle somewhat less than 180°, are straight and, apart from the spines, simple. The second theca grows parallel to the first till past its aperture where it bends nearly at right angles and the upward flexure of the stipe commences. All second thecae begin to show sigmoidal traits and all the following thecae are characteristically only slightly sigmoidal, with the free ventral wall straight and parallel to the stipe and the aperture introtorted and hence also introverted. The overlap is usually small in the order of one quarter, and the inclination also small in the order of 10° to 15°.

The sicula is always incomplete but would be simple. It has a slight apertural virgella.

MATERIAL: Only three specimens were found, rather poorly preserved as flattened carbonaceous films in a fine, bedded tuff.

HORIZON AND LOCALITIES: This species has been found only at one horizon in the Angullong Tuff (Co/I/144) approximately 2,000 ft above its base, which would probably give it a Bolindian age. The occurrence appears to be restricted but this could be due to the unfossiliferous nature of the Angullong Tuff about this horizon.

DISCUSSION: The most distinctive feature of *D. minimus* is its small size, and this serves to distinguish it easily from other dicellograptids. The axil is also remarkable in that the first thecae separate at an angle less than 180° and the second thecae have to bend more than usual to counter this and give the final angle of divergence. They are bent through nearly 90°.

The thecae being slightly introtorted and introverted would place the species into Elles & Wood's group II or III.

Dicellograptus cf. **D. caduceus** Lapworth

In 1954, Sherrard identified *Nemagraptus explanatus pertenuis* from the area. Examination of her specimens (1954, Pl. 10, fig. 2) indicates that they are in fact fragments of a dicellograptid of which genus *D. caduceus,* because of the curved nature of its stipes, appears to be the most likely.

The specimens are rather poorly preserved with very few thecae separable from the general compressed common canal and thecae. Where well displayed the thecae

show pronounced sigmoidal curvature typical of the dicellograptids rather than the more gentle curvature one would expect from a member of the Leptograptidae.

Sherrard (op. cit.) describes the form as 'Rhabdosome incomplete. Very slender, graeefully curved stipes, dorsally flexed describing almost semicircles . . . Angle of divergenee 60°, square axil . . . Thin branches about 1 em long rarely project from a theca.' My present observations differ somewhat from this description, and, though I agree that the stipes are usually dorsally flexed almost into semieircles, I disagree with the rest of Sherrard's points. I can find no siculate end nor any definite cladia. In my opinion these specimens are simply badly mutilated fragments of a long curved branch of a dicellograptid of which the sigmoidally curved *D. caduceus* seems to be the closest approximation.

If we assume a stipe of eonstant curvature twisted through 180° we end with a form very similar to Sherrard's figured specimen. Furthermore, at the point of twisting we might expect to find a slight kink which had apparently been interpreted as a sicula, though it could never reach the dimensions of the large sicula of *N. explanatus pertenuis*. Again, examination of the stipes failed to reveal any branches and the cladia thought to be present are either further breakages of the stipe (for branches at the tip) or fortuitous superimpositions (for branches along the stipe). Lastly the stipe is not as narrow as previously described and most specimens can be seen to taper consistently from the extremity of what would be one stipe to the extremity of what would be the other, rather than to expand equally away from the point of inflection (the sicula). The width may be as low as 0·4 mm but most have a width of twice this at about 0·8 mm.

Horizon and Localities: The specimens were only found at one locality in the Mallongulli Formation (Grid Ref. 818, 450).

Genus **Dicranograptus** Hall 1865

Dicranograptus cf. **D. kirki** Ruedemann 1947

(Fig. 1e-g)

Dicranograptus cf. *kirki* Harris & Thomas 1955, p. 10, figs. 19, 20 & 21.

Diagnosis: The extremely short biserial portion with only three thecae, the '*D. clingani* type' thecae, and the early curving uniserial stipes help to separate this form.

Description: The rhabdosome has the typical Y shape, slightly modified into a tuning fork, and is typified by a very short biserial portion. This biserial portion is usually about 2·5 mm in length and has in all cases three theeae (often theca 4^1 may start before the bifureation). The biserial portion is essentially parallel-sided with a width of 0·9 mm, but some of the speeimens show a slight fusiform tendeney. At the point of bifurcation the uniserial branches diverge with an axillary angle around 50° or 60° which they fairly well maintain, giving the normal Y shape, or when the angle decreases till they become nearly parallel, a tuning fork shape. The smaller forms are more usually of the Y shape but this may be merely that the change of eurvature has been delayed and not yet reached. The uniserial stipes are virtually parallel-sided with a width surprisingly large compared to the biserial portion: 0·7 mm compared to 0·9 mm. They may reach a length of 2 em but 5 mm is a more common maximum.

The thecae probably vary substantially in different parts of the rhabdosome, but are in all cases simple for the genus, being of the *D. clingani* type. Some of

the thecae bear spines which may reach a length of over 1 mm. Specimen 9639 shows spines on the biserial portion thecae, the spines being situated nearly half way along the free wall, and specimen 9638 shows a spine on a theca of the uniserial portion with the large spine closer to the point of inflection of the theca. The thecae where visible have the free wall subequal in length to the covered wall. The aperture is simple, normal to the stipe and situated in a deep sharp excavation. Thecae measure about 1·0 mm in length and 0·3 mm in breadth and number 14 to 15 per cm in the biserial portion and less (about 12 per cm) in the uniserial portion.

The sicula is never well seen, being almost entirely buried by the first two thecae, but its strong, prominent virgella may usually be seen.

MATERIAL: Some 25 specimens have been collected but most are poorly preserved as thin carbonaceous films in either fresh or leached rock.

HORIZON AND LOCALITIES: This form has been found at only the one locality (Co/I/139) at the base of the Mallongulli Formation.

DISCUSSION: Owing to the poor preservation of the finer details, more emphasis has been placed on overall morphologieal details; even so the number of possible species remains large. However, as all the species in the group are obviously close relations, their ranges are also very similar (Ross & Berry 1963, Table 2, Sheet 1). As pointed out by Harris & Thomas (1955, p. 10) 'the dicranograpti from this region (are) characterized by a short parallel-sided spinose biserial portion. The Wellington River forms in this group—*Dicranograptus hians, D. teali* and *D.* cf. *kirki*—are probably Victorian equivalents of *D. clingani* . . . The Victorian forms seem to occur on about the same horizon as *D. clingani* does in Britain.'

It is very hard to separate *D. kirki* and *D. teali* as the major difference lies in the curvature of the uniserial stipes while the range of other properties in both overlap to a considerable extent. Very few of the specimens were of great length so most could be the early stages of either *D. kirki* or *D. teali.* In only one specimen (Fig. 1f) did the uniserial stipes cross, and this specimen showed obvious torsion. However, a comparison of this material and the material in the Geological Museum, Melbourne, collected by Harris & Thomas, who are the authors of *D. teali,* would seem to place the species as specimens identified by them as *D.* cf. *kirki.*

These specimens differ somewhat from *D. kirki* as described by Ruedemann, firstly in that the number of thecae per cm is much higher. Ruedemann (1947) gives the count as 8 to 10 per cm while Ross & Berry (1963) quote 8 to 9. Neither author differentiates between the biserial and uniserial stipes, which may or may not be taken to indicate that they are equal. In the species here described there is a difference, the biserial portion having 14 to 15 per cm on extrapolation, far more than the American *D. kirki,* but the uniserial portions have only 10 to 12, a little closer to the American values. *D. kirki* and *D. teali* from America appear to have fewer thecae per cm than Australian specimens (Ross & Berry 1963).

Another difference lies in the biserial portion which in the American species may have from 3 to 5 thecae in it and have a proportionately greater length. At the Wellington River and at Cliefden there are apparently a fixed number, three.

It is probably this species which was previously identified from the area as *D. zigzac* (Sherrard 1954).

Family Diplograptidae Lapworth 1873
Subfamily Climacograptinae Frech 1897
Genus **Climacograptus** Hall 1865
Climacograptus tridentatus Lapworth 1876

(Fig. 4a)

Climacograptus bicornis var. *tridentatus* Lapworth 1876, Pl. 2, fig. 52.
Climacograptus bicornis var. *tridentatus* Lapworth 1877, Pl. 6, fig. 38c.
Climacograptus bicornis var. *tridentatus* Elles & Wood 1906, p. 195; Pl. 26, figs. 9b, c.
Climacograptus tridentatus var. *maximus* Decker 1935, p. 707, figs. 1s, t.
Climacograptus tridentatus var. *maximus* Ruedemann 1947, p. 439; Pl. 75, fig. 17-26.
Climograptus cf. *C. tridentatus* var. *maximum* Ross & Berry 1963, p. 131; Pl. 9, figs. 9, 21.

Diagnosis: The rhabdosome is very large and robust for the genus and the proximal end is characterized by the presence of three or more large and robust spines of subequal length. One of these is a great enlargement of the sicular spine and lies parallel to the axis of the rhabdosome, and the other two or more extend almost at right angles to it, though sometimes they may droop conspicuously.

Description: Only the proximal fragment of a rhabdosome 15 mm in length, excluding spine, was found. The rhabdosome widens fairly evenly and the sides are almost straight; the minimum width is 1·2 mm and the maximum 1·9 mm. The most distinctive feature of the rhabdosome is the proximal end which is decorated by three prominent spines. One spine is directed along the axis of the rhabdosome with a maximum width of 1 mm and an incompleted length of 7 mm. The two lateral spines are slightly slimmer with widths of 0·6 mm and lengths probably proportionately smaller (incomplete lengths 3·5 mm and 4·5 mm). They are fairly rigid but have slight tendency to droop distally. The thecae number 9 to 9½ per cm in mature portions of the rhabdosome.

The thecae are poorly seen as the specimen has been flattened in a subscalariform position so that only one series can be seen, and that with the thecal apertures nearly full on. They are probably fairly simple climacograptid thecae as no marked modification could be seen.

There is no sign of a sicula owing to the large amount of membrane surrounding the junction of the spines.

Material: Only one incomplete specimen was found as a shallow impression in fine, shaly Mallongulli Formation.

Horizon and Localities: The only specimen found came from locality Co/I/131, near the top of the Mallongulli Formation.

Discussion: A former variety of *C. bicornis, C. tridentatus* has been elevated to specific rank as the distinctiveness of the form became apparent and the vast variation within it known. 'This very large variety has thecae typical of *C. bicornis* which typify Lapworth's variety *tridentatus*. As this proximal three-spined type of *bicornis* remained so constant through several formations *tridentatus* is raised to the position of a species, and the new varietal name of *maximus* is added to this greatly enlarged form' (Decker 1935, p. 707). The author agrees with Decker on the individuality of *C. tridentatus* but, as may be seen from the synonomy, feels that the varietal name *maximus* should be dropped as the figures of Lapworth show his forms to be as large as Decker's.

Ross & Berry (1963) have stated that they feel that *C. tridentatus maximus* (or more correctly *C. tridentatus*) 'may be included as a . . . end member' of *C. hastatus*. However, this author does not subscribe to this interpretation of the

two species but prefers to argue along the lines set out by Harris & Thomas (1955) that the relative proportions or the spines distinguishes them from each other, a criterion also adopted by Berry in a later paper (Berry 1966, p. 163). Harris & Thomas point out that there may be more than three spines in both species but in all cases the virgellar projection is the most prominent feature in *C. hastatus* while the lateral spines are almost equal to it in *C. tridentatus*. This simple criterion appears to be the safest measure in sorting out the large number of subspecies appearing in both species, as there is now large overlap. The specimen here described was incomplete and consequently the identification is not conclusive. The three proximal spines present appear to be subequal in length, unless the sicular spine is of extreme length, and so the form would probably better fit in the *C. tridentatus* group and, as the size is probably equal to that of Lapworth's type, it could be placed as *C. tridentatus*.

Climacograptus bicornis (Hall) 1847

(Figs. 3d, 3)

Climacograptus bicornis Elles & Wood 1906, p. 193-195; Pl. 26, fig. 8a-f.
Climacograptus bicornis Sherrard & Keble 1937, p. 307, text-fig. 1.
Climacograptus bicornis Ruedemann 1947, p. 424; Pl. 72, fig. 44-52.
Climacograptus bicornis Sherrard 1949, p. 67, text-figs. 10a, b.

DESCRIPTION: The rhabdosome is small for the species, attaining a maximum of only 2 cm. The initial width (thecae 1^2 and 2^2) is 0·7 mm and the rhabdosome widens steadily to 1·8 mm after about 1 cm, after which it is almost parallel-sided to the end. A median septum can be discontinuously seen within the rhabdosome and in one specimen (immature? only 12 mm in length) a short, slender virgula extends for a few millimetres past the distal extremity. The thecae number close to 10 per cm in distal portions but this value rises substantially proximally where the thecae become markedly smaller. The rhabdosome is typified by having two large spines at its base. The spines diverge at an angle around 100° though they tend to droop somewhat, distally, giving them a curved shape. The largest spines have a length of 1·8 mm and taper gradually from a very small initial width (0·1 mm) to their ends.

Because of the half profile and sub-scalariform orientation of the rhabdosome most of the thecae appear distorted and their shapes hard to determine. Where well seen they are typical, simple, climacograptid thecae which overlap by approximately 1/3 and whose apertures lie in an open excavation with depth about ¼ the width of the rhabdosome. Distally the thecae appear to have a length of 1·5 mm. Early thecae tend to have deeper apertures and are markedly smaller than those in the later rhabdosome.

No sicula could be seen because of the adaptation of the proximal end, and if a virgella is present it must be also covered.

MATERIAL: Only three specimens were found in a friable badly leached rock.

HORIZON AND LOCALITIES: All the specimens came from locality Co/I/139 at the base of the Mallongulli Formation.

DISCUSSION: This very variable species has such a wide range in the dimensions of its morphological features (Ruedemann 1947, p. 425) that much discussion here is out of place. However, the specimens here described do appear to fit well into Elles & Wood's (1906) more restricted definition and seem similar to the English forms.

The species is uncommon. Only 3 specimens were found, and the only prior reference to its presence in this area is in an unpublished report (Öpik 1952).

Climacograptus cf. **C. supernus** Elles & Wood 1906

(Fig. 3f)

Diagnosis: A small climaeograptid with the proximal end decorated by two curved, slender spines, one originating from the sicula, the other from the point of inflection of theca 1^1. The thecae are also small and although they overlap slightly the thecal count is high. The excavation is short and shallow, never occupying more than one quarter of the width of the rhabdosome.

Description: The rhabdosome is small, the only specimen found measuring 7·5 mm in length. From a proximal width of 0·8 mm the rhabdosome widens steadily to 1·1 mm as a maximum for this fragment, leaving the sides of the rhabdosome almost straight. The most distinctive feature of the rhabdosome is the proximal end which is decorated by two slender, curved spines. These spines reach a length of 1·8 mm but have a width of only 0·15 mm. They diverge initially at an angle of approximately 120°, evenly divided by the axis of the rhabdosome, but curve in a drooping manner to reduce this angle. A virgula or median septum may be seen to run through the full length of the rhabdosome.

The thecae are very badly preserved but appear to be of ordinary climaeograptid type, though no further details could be discerned and no thecal count made. No sicula could be seen owing to the enveloping nature of the initial thecae, but the long virgella could be seen and a suggestion of its inclined position.

Material: Only one specimen poorly preserved in a very leached rock was collected and permeating solutions appear to have largely obliterated any sharp boundaries.

Horizon and Localities: The only specimen came from locality Co/I/131 near the top of the Mallongulli Formation.

Discussion: The bad preservation of the specimen made the identification uncertain, but the distinctive proximal end and small size limit the choice to two species, *C. supernus* and *C. diplacanthus*. These two forms are very similar and may one day be brought together into one species.

Both these species are of small size and have the proximal end decorated by two slender, drooping spines. Bulman states (1933) that one of the spines of *C. diplacanthus* comes off theca 1^1, which agrees with *C. supernus* of Elles & Wood, but states the other spine of *C. diplacanthus* comes off the sicula and is in fact the virgella. Elles & Wood claim that the second spine of *C. supernus* comes off theca 2^1, but this could easily have been a mistake as they recognize the oblique orientation of the sicula. An examination of their figures is not conclusive but would tend to support this theory.

The larger dimensions of the initial width of the polypary in this specimen could be explained along the lines of Elles & Wood, in that the sicula had been pushed through the rhabdosome, adding its bulk, or part thereof, to that of the rhabdosome proper. The difference in the depths of excavation between these specimens, those of Elles & Wood and of Bulman could be explained by the fact that Bulman's *C. diplacanthus* was preserved in three dimensions whereas the others were flattened. This also explains the somewhat narrower widths of Bulman's specimens.

The possibility of this specimen being a juvenile *Cl. bicornis* also exists. Though

not well shown in Fig. 3f, when the actual specimens are compared this specimen is much more slender and slight than the *Cl. bicornis* specimens. Though the width at Th1[1] is similar, this is due to the widening effect of the impressed sicula, and just above the sicula the specimen is much narrower than *Cl. bicornis*. The spines are also too slender to be confused with examples of *Cl. bicornis* from the same locality.

Climacograptus fusiformis sp. nov.

(Fig. 3g-i)

Diagnosis: A medium-sized climacograptid typified by a fusiform shape; that is, widening gently in a non-linear fashion, convex outwards, from a round proximal end. Thecae climacograptid with a deep, narrow, almost subrectangular excavation and markedly alternate position, number approximately 10 per cm. Sicula not obvious but possessing a short, stout virgella. A virgula or medium septum may be seen within the rhabdosome and a virgula may often be seen extending past the distal end, especially in the smaller (immature ?) forms.

Description: The rhabdosome may reach a considerable length (close to 3 cm) but is more commonly smaller with a length around 1½ cm. The proportions of both the larger and smaller forms are, however, approximately the same and all are characterized by a fusiform shape. As a rule the rhabdosome widens fairly constantly for the first third of its length when the maximum width is reached (2·1 mm for the larger, 1·6 mm for the smaller). From here to about the last fifth it is virtually parallel-sided but then it begins to taper again, though not as markedly as the initial widening. The proximal end is well rounded by the shape of the initial theeae, but the distal end is more a rounded rectangular shape. A possible median septum can be discerned in some specimens but apparently is incomplete, there being no sign of it in the proximal third of the rhabdosome. The virgula passes through the rhabdosome and extends past the distal end for up to 5 mm; it is always thin. Theeae number 10 per cm in mature portions but may number 12 or more towards the sicula. The thecae are usually observed in a slightly subscalariform view but can be seen to belong to Elles & Wood's group II. The free ventral edge is quite straight and nearly parallel to the axis of the rhabdosome and the aperture is somewhat introverted. The excavation is sharp with the angle of geniculation 90°, and is almost completely filled by the previous theca, leaving intermediate deep, narrow rectangular slots. The excavation is a little more than one fifth the width of the rhabdosome. Other dimensions of the thecae could not be measured because of orientation.

The sicula is almost entirely masked by the initial theeae which grow right down to its aperture, but its position is always marked by a stout virgella sometimes over 2 mm in length though more often under 1 mm. The virgella is sigmoidal as the sicula is slightly curved and the virgella neutralizes this by curving in the opposite direction.

Material: The species is often prolific on certain bedding planes and a large number of individuals have been collected. The large individual on specimen 9664 is selected as the holotype. The preservation varies from a carbonaceous film in fresh rock to low impressions in leached material.

Horizon and Localities: The species was only found at the one locality at the base of the Mallongulli Formation (Co/I/139).

Discussion: This is probably the form which had previously been identified as *C. antiquus* and *C. antiquus* var. *linearis* (Sherrard 1954, Stevens 1954, respec-

tively) as it does bear some resemblance to this species. However, the proximal end lacks the development of the membranes of *Cl. antiquus* and its subspecies, and also the virgula is less prominent, being both thinner and shorter than that of *Cl. antiquus* and its subspecies. The overall shape is also different in the mature rhabdosome, not tapering distally as in *Cl. antiquus* but ending in an angular rather than rounded manner. An Australian form of *C. antiquus* has been separated by Harris as *C. riddellensis* (Harris 1924) but both these species differ from *C. fusiformis* in having different apertural excavations and the two initial thecae modified by short spines.

It also bears a strong resemblance to *C. affinus* which T. S. Hall described from Mandurama (T. S. Hall 1900, p. 16, Pl. 6, fig. 1) but differs from it in a number of points and apparently came from a different horizon (associated with *Agnostus*). Hall's description is apparently of one specimen only and very limited. The two species differ in overall shape, *C. affinus* expanding more rapidly and having a larger portion parallel-sided. The thecae also number more in *C. affinus*, 12 in 1 cm (misprint?) and seem to lie in deeper excavations than those of *C. fusiformis*. Lastly, Hall appeared to think that a long, straight virgella (3 mm) was typical of the species, while in *C. fusiformis*, though sometimes large, it is usually not as conspicuous and tends to be somewhat sigmoidal.

Climacograptus modestus as figured by Ruedemann (1947, Pl. 73, fig. 36) resembles *C. fusiformis* closely but his type for the species bears spines on the initial thecae and is probably conspecific with *C. antiquus*. In his description Ruedemann makes no mention of spineless forms, though he has bracketed some in his figures, so we must take his spined type as the *forma typica*.

Climacograptus tubuliferus Lapworth 1876

(Fig. 3a-c)

Climacograptus tubuliferus Lapworth 1876, Pl. 2, fig. 49.
Climacograptus tubuliferus T. S. Hall 1902, p. 6; Pl. 13, fig. 5; ? Pl. 14, fig. 4.
Climacograptus tubuliferus Elles & Wood 1906, p. 203; Pl. 27, fig. 8, text-fig. 134.
Climacograptus tubuliferus Sherrard & Keble 1937, p. 307, text-fig. 2; Pl. 15, fig. 3.
Climacograptus tubuliferus Ruedemann 1947, p. 440; Pl. 75, fig. 54-56.
Climacograptus tubuliferus Sherrard 1949, p. 71, text-fig. 13.
Climacograptus tubuliferus Harris & Thomas 1955, p. 8, fig. 10-12.
Climacograptus tubuliferus Ross & Berry 1963, p. 132; Pl. 10, figs. 1, 2.

Diagnosis: As the specific name suggests the graptolite is typified by having a hollow tube running along its full length, encasing the virgula while within and without the rhabdosome, and the virgella at the proximal end. The rhabdosome widens gradually for about 1½ cm in a linear manner after which it is parallel-sided to its distal end. The thecae are almost of amplexograptid pattern with a very sharp geniculation, and number about 10 per cm in mature portions.

Description: The rhabdosome is variable in size, the largest reaching a length of 23 mm excluding virgella and virgula, but a more common length is 15 mm. The rhabdosome commences from a narrow, rounded proximal end 0·8 mm in width, and expands evenly for about 1·5 cm to a width of a little over 2 mm. The straight sides so formed are extremly characteristic of the species. After the maximum is reached the rhabdosome is almost parallel-sided to its truncated distal end. Another distinctive feature of the species is the prominent virgula which can sometimes be seen for a millimetre or so within the rhabdosome and always projects prominently past its distal extremity. The virgula ranges greatly in size but apparently a length of between three-quarters to the same as the length of rhabdosome is characteristic. The virgula is usually surrounded by a tubular membrane

which when flattened may reach a width of 0·8 mm. It commences with a narrower portion and doubles in width distally, sometimes widening gradually and at other times suddenly.

The theeae cannot be measured accurately, as in the flattened preservation they are seen only in outline, but they number 10 per cm in mature portions of the rhabdosome and up to 14 to 15 per cm towards the sicula. The geniculation is almost amplexograptid, the infragenicular wall is straight and inclined slightly outwards and the suprageniculär is strongly concave. The excavation varies in depth from one third to one fifth the width of the rhabdosome with one quarter the usual value, and in this the aperture is straight and slightly introverted.

The sicula is almost totally enclosed by the downward growth of the two initial thecae but its position is always marked by a long virgella. The virgella usually reaches one tenth the length of the rhabdosome and is itself slender though it may be covered in part by an extension of tubular membrane. This tube when flattened may reach a width of 0·3 mm and is commonly around 1 mm in length. It gives the virgella a characteristic appearance.

Young Forms: In this area mature forms of this species are the exception. These immature specimens are identical with the early stages of mature ones except that they lack the tubular membrane in the axis. The proportions of the various components are the same in both mature and immature individuals with the virgula subequal to, and the virgella one tenth, the length of the rhabdosome. The tubular membrane apparently does not make an appearance until the rhabdosome reaches a length of about 10 mm when it begins to grow up the virgula. It is even later in appearance surrounding the virgella and both virgula and virgella can often be seen protruding past it.

Horizon and Localities: This fossil is widespread in the lower parts of the Mallongulli Formation, occurring at many localities.

Material: A large number of specimens were collected but all were flattened forms usually preserved merely as outlines. Though a few single specimens were found, the species appeared to be mostly gregarious and often occurred in such numbers that one obliterated the other.

Discussion: It is surprising that such an abundant fossil was missed by the early workers of the area. The only identified graptolite in the past literature which bears any resemblance to it is *C. antiquus,* but the difference between these is so large that *C. tubuliferus* could not have been mistaken for this species.

The species is made distinctive by the tubular membrane which surrounds the virgula and virgella of mature forms. This tube was apparently thin walled but had a relatively large diameter. Though primarily cylindrical or gently widening distally it sometimes dilated, usually towards the distal extremity but sometimes closer to the point of emergence from the rhabdosome, and contracted again distally. Only the most mature specimens (the longest) have their virgella almost covered by this membrane, it being more common to see it covering only the early portion.

The species was only rarely found as single individuals, but mostly in large numbers fairly closely packed. This could be due to the fact that the species lived as synrhabdosomes which broke up upon 'death'. No attached floats were found but clusters of specimens in almost parallel orientation were seen and could represent synrhabdosomes just broken (specimen 9668).

Another feature which could be related to a 'colonial' habit of life is the

frequency of immature forms. Some bedding planes are covered by numbers of specimens all at the same stage of growth with less and more mature specimens rare. This would of course be due to the collapse of the float, etc., causing the whole 'colony' to settle to the bottom. Harris & Thomas (1955) have also experienced the same feature in Victoria. They write 'the Wellington River collection includes examples which differ greatly in size. Characteristic large forms, and also a group in which maturity seems to be reached in a length of little over 1 cm.' This size coincides with the common length in the Cliefden Caves district and it may be that when this size was reached, at least some of the synrhabdosomes (the most tightly packed?) became unstable and either broke up or sank. The presence of the very long virgula may also indicate that the specimens belonged to a synrhabdosome.

Subfamily Diplograptinae Frech 1897

Genus **Diplograptus** McCoy 1850

Diagnosis: 'Thecae strongly sigmoidal with apertures in broad semicircular excavations (amplexograptid at proximal end) gradually becoming more gently sigmoid (glyptograptid) and almost straight distally; periderm attenuated and with apertural lists proximally, cross section ovoid or nearly rectangular.' (Bulman 1955.)

Discussion: The above diagnosis, like most of the others before it, emphasizes the variation of thecal shape along the rhabdosome. The general opinion had been that the early thecae are sharply sigmoidal (climacograptid or amplexograptid) gradually grading into thecae without a distinct geniculation (glyptograptid to almost straight orthograptid) later. But also, as mentioned in the diagnosis above, the periderm is very thin and this may lead to strange deformations upon compression.

The author agrees with Jaanusson & Skoglund (1963) that it is difficult to settle generic reference on many species and the species described below is one such. Jaanusson & Skoglund state: 'The type species of the genus *Diplograptus pristis* does not quite agree with this definition (Elles & Wood, Bulman (1955)). In this species the proximal thecae have a poorly defined geniculum, and their shape is closest to the glyptograptid type, whereas the distal thecae assume the shape of the orthograptid type (Skoglund 1963). A gradual change in the shape of thecae in distal direction can be observed in many diplograptids, such as *Orthograptus apiculatus* (Bulman 1945, Pl. 6, figs. 1, 2, 4, 8), *Glyptograptus* cf. *teretiusculus* (Jaanusson 1960, Pl. 3, fig. 10), and *Amplexograptus leptotheca* (Bulman 1945, Pl. 4, fig. 15, Pl. 3, fig. 10), to give just one example from different genera. The degree of change does not seem to be much greater in *Diplograptus pristis* than in some species currently referred to *Glyptograptus* or *Orthograptus*. In flattened specimens the appearance of the proximal thecae is often climacograptid in *D. pristis* due to a deformation of these thecae by compression (Skoglund 1963), and this throws some doubt on the correctness of the interpretation of thecal shape in several other species which are currently referred to *Diplograptus* and from which only strongly flattened material is known.'

Diplograptus ingens wellingtonensis Harris & Thomas 1955

(Figs. 5e, f)

Diplograptus (Mesograptus) ingens T. S. Hall, var. *wellingtonensis* Harris & Thomas 1955, p. 6, figs. 31, 32.

DIAGNOSIS: From a very narrow proximal end, the rhabdosome widens for about two thirds of its length, after which it slowly narrows to the distal end. The nature of the proximal widening is characteristic as it results in the rhabdosome having a slightly concave outline. The thecae are always of glyptograptid pattern and even at the proximal end show no pronounced geniculation.

DESCRIPTION: From a relatively narrow proximal end the rhabdosome rapidly broadens reaching four times its initial width at two thirds of its length (1·1 mm to 4·0 mm). From this maximum a slight tapering occurs to the distal end, which appears to be somewhat rounded. The rhabdosome may reach a length of 2½ cm. Both specimens showed the virgula extending past the distal extremity for an unknown distance and its path, or that of the median septum, through the rhabdosome. The thecae number 10 to 11 per cm in mature portions of the rhabdosome, and slightly higher proximally, though an accurate count here could not be made.

The thecae, typical of the genus, vary along the rhabdosome but bad preservation usually allows only the outline of the free ventral edge to be seen. Proximally the thecae have rather sigmoidal glyptograptid form without any marked angular geniculation. The glyptograptid shape gradually grades along the rhabdosome into a straighter, almost orthograptid, form though some sigmoidal character is still retained. The more mature thecae have a length of approximately 1·2 mm and a width of 0·5 mm. Each theca overlaps its predecessor by about one third and is inclined at an angle of approximately 40° to the axis of the rhabdosome. The aperture is slightly introverted and may be a little convex.

The sicula cannot be seen since the initial two thecae cover it. A virgella may be seen on one of the specimens and appears to be of small size.

MATERIAL: Only one slab with two badly preserved specimens was collected.

HORIZON AND LOCALITIES: The slab came from Trilobite Hill (Co/I/139) at the base of the Mallongulli Formation.

DISCUSSION: The most distinctive feature of this subspecies is the lack of any sign of angular geniculation of the thecae on any part of the rhabdosome, there being no sign of any amplexograptid or climacograptid thecae. As outlined in the discussion of the genus, the author does not believe that this lack of geniculated thecae debars this species from the genus *Diplograptus*. Harris & Thomas, when erecting the new subspecies, stated that they were only separating specimens designated by Hall (the author of the species) as belonging to the one species, so apparently Hall considered them to be diplograptids.

A comparison of the Cliefden specimens with the figures of Harris & Thomas, as well as with the types in Melbourne, verify that the two forms are identical.

Genus **Orthograptus** Lapworth 1873

Orthograptus truncatus aff. **pauperatus** Elles & Wood 1907

(Figs. 4b, c)

DIAGNOSIS: The rhabdosome has the typical '*truncatus*' outline, but is characterized by being more slender. It may reach a length of 3 cm with a maximum width of only 2·8 mm. The thecae overlap each other by from one half to two thirds of their lengths and are inclined at 40° to the axis of the rhabdosome. They number 10 to 11 per cm in mature portions.

DESCRIPTION: The rhabdosome is straight and commences with a width of 1·0 to 1·2 mm excluding spines. It then widens gradually to a maximum of 2·3

to 2·6 mm at about half the length, after which it may proceed parallel-sided to the distal end, or more commonly begins to taper to a truncated end about half as wide again as the proximal end. The maximum length is 3 cm but the majority reach only 2 cm. There is no sign of a virgula protruding past the distal end.

The thecae are simple straight tubes. They are parallel-sided and as the aperture is normal, or nearly so, to their axes, it is very conspicuously everted. Occasionally the aperture may become horizontal, or normal to the axis of the rhabdosome, or may have a slight undulation. In mature sections of the rhabdosome the thecae have a length of 1·5 to 1·6 mm and a width of 0·5 to 0·6 mm. They overlap each other by half to two thirds their lengths, are inclined at about 40° to the axis of the rhabdosome and number 10 to 11 in 1 cm in mature portions of the stipe. Towards the proximal end the overlap and inclination remain fairly constant but the length, accompanied by an appropriate decrease in width, becomes less and they may number up to 15 in 1 cm. The two initial thecae are different in having mesial spines which may reach over 0·2 mm in length but which are usually less conspicuous.

The sicula was seen in one specimen and is a simple cone 1·3 mm in length, reaching to the aperture of theca 2^2, and 0·3 mm in width. Its position is always marked by a virgella which may reach a length of 0·4 mm.

Material: The preservation is generally poor as the walls of the rhabdosome were apparently thin and in the leached rock only very shallow impressions remain.

Horizon and Localities: The species ranges almost throughout the Mallongulli Formation and so may be found at almost any of the localities where preservation is good. All the specimens described here came from one locality in the Mallongulli Formation (Co/I/139).

Discussion: This subspecies has the relatively narrow '*truncatus*' shape typical of *O. truncatus pauperatus,* and may be an Australian equivalent.

Firstly the length is somewhat less than the English form, the maximum size being only 3 cm, and the majority being much less than this. The size does vary considerably but the variation is gradual and no distinctive groups could be separated. The smaller specimens reach a maximum width of only 1·5 mm after a commencing width of 0·8 mm.

As well, the maximum width is reached at a much later stage in the growth of the rhabdosome, at halfway rather than in the first 5 mm as stated by Elles & Wood. The thecae number fewer per centimetre (10 compared with 12 to 14) than the English subspecies and since the overlap and inclination are approximately equal, they must be slightly longer.

The only descriptions of this subspecies in Australia were done by Mrs K. Sherrard (1949, 1962). In 1962 she described a specimen with the rhabdosome the same length and initial and maximum widths, and with thecae of the same length, inclination, overlap and thecal count of 13 per 1 cm.

Orthograptus calcaratus clavensis subsp. nov.

(Fig. 4f-i)

Diagnosis: The rhabdosome rapidly widens from a narrow (1·2 mm) proximal end, reaching the large width of 4·0 mm within 2 cm, after which it is virtually parallel-sided. The proximal end is characterized by a virgella 1·5 mm in length and two mesial spines up to 1·0 mm in length, one on each of the initial thecae.

The thecae number 10 to 11 in 1 cm in mature portions and overlap each other by one third, rarely more, and are inclined at 30° to the axis of the rhabdosome.

DESCRIPTION: The rhabdosome is straight and from a proximal end 1·2 mm in width rapidly widens to 4·0 mm or less, depending on the stage of growth reached. The distal end is usually angular and the virgula may be seen to extend past for some distance. Sometimes either a median septum or the virgula may be seen to pass through the middle of the rhabdosome but it is impossible to distinguish between them in this state of preservation. The specimens collected were as a rule incomplete but from the various pieces it can be deduced that mature individuals reached at least 5 cm in length. The thecae number from 10 to 11 per cm in mature portions of the rhabdosome and rather more towards the sicula.

The thecae range in length from 1·5 mm to just under 2 mm, and have a width of 0·55 mm for the shorter to 0·7 mm for the longer. They are not straight tubes but show a slight, gentle sigmoidal curvature, forming a slight excavation for the preceding theca. The aperture is fairly straight but appears a little uneven towards the outer corner where it is drawn out into a small denticle. The thecae are inclined at 30° to the rhabdosome but their apertures are normal to the axis of the rhabdosome. The first two theeae are ornamented, each with a spine up to 1 mm in length projecting from them. These spines are in a mesial rather than apertural position. Though they are stiff they have a slight tendency to droop.

No sicula was seen but its presence is always indicated by a stiff virgella which may reach a length of 1·5 mm.

YOUNG FORMS: Although no very young specimens were found, specimen 9683 shows a number of immature individuals. These are made distinctive in that even in their short length (15 mm) they had attained a width nearly 3 mm. They show all proximal features already developed.

HORIZON AND LOCALITIES: All the specimens came from the one locality, Co/I/144. This locality is in the Angullong Tuff, about 1500 ft or more above its base.

MATERIAL: The preservation, as already noted, is not very suitable; the combination of semi-relief and only remnants of carbon make it difficult to work with. As well, the graptolites were frequently bent as the rock was contemporaneously deformed. A thecal shape was often only a partial outline until the preceding theca overlapped it, but occasionally a complete outline could be seen.

Specimens 9683-9687 have been lodged at Sydney University and the specimen figured as Fig. 4f from slab 9683 is designated as the holotype.

DISCUSSION: The species falls into the *'calcaratus'* group of the orthograptids in having three large spines at the proximal end and in having slightly sigmoidal thecae with apertures horizontal rather than strongly everted as in the *'truncatus'*.

Within the *'calcaratus'* group it is distinguished by a great breadth after a narrow proximal end. The maximum width of 4 mm is passed by some members of this group, e.g. *O. calcaratus priscus,* but these all start with an initially greater width of 2 mm or more. *Orthograptus calcaratus clavensis* also has the highest rate of expansion of the rhabdosome within the group.

The thecae on the whole are much the same as for the others of the group in that they are slightly sigmoidally curved but appear to be inclined at a slightly higher angle to the rhabdosome. They overlap by about one third, which is more like *O. calcaratus* but rather less than the other subspecies.

Orthograptus whitfieldi (Hall) 1859

(Figs. 5i, j)

Diplograptus whitfieldi Lapworth 1876, Pl. 2, fig. 45.
Diplograptus whitfieldi Lapworth 1877, p. 134; Pl. 6, fig. 21.
Diplograptus (Orthograptus) whitfieldi Elles & Wood 1907, p. 227, figs. 149a, b; Pl. 28, fig. 6a-d.
Glossograptus whitfieldi Ruedemann 1947, p. 457-458; Pl. 77, fig. 23-26.

Diagnosis: Rhabdosome short, but extremely broad for its length. Proximal end narrow and rounded. Rhabdosome widening rapidly in a non-linear manner (convex outwards) to the truncated distal end, from which may extend a virgula of variable length. Thecae typically orthograptid but modified by long drooping apertural spines, slightly ascending in direction.

Description: The rhabdosome is short, the longest only measuring 10 mm and most being less than this. The width, however, is relatively large for its length, the 10 mm specimen having a width of 3·1 mm exclusive of spines, a length-breadth ratio of nearly 3:1. The maximum width ranges down to 2·0 mm in the slightly smaller forms. The proximal end is rounded and in all cases has a width of nearly 1·2 mm. The number of thecae per cm range from 10 to 12½ in mature portions of the rhabdosome. Proximally the number of thecae rises to about 14 per cm.

The thecae are of typical orthograptid pattern in that they are straight and nearly parallel-sided but are made distinctive by the presence of large apertural spines. The thecae range in length from 1·6 mm to 1·3 mm and in width from 0·6 mm to 0·4 mm and are inclined to the axis of the rhabdosome at angles ranging from 30° to 45°, the latter value being infrequent. Each theca overlaps the following one by approximately one third. The spines grow upwards and outwards from dorsal part of the thecal lip, and may reach over 2 mm in length in the distal portions of some rhabdosomes, but 1 mm is a more usual length. Though reasonably stout the spines have a tendency to droop and after starting in an upward direction may end in a horizontal or even declined direction.

The sicula is hidden by the initial few thecae. No virgella of any size was noticed. A virgula or median septum may be seen to run the length of the rhabdosome and a short virgula may extend past the distal end.

Horizon and Localities: This species was found only around Trilobite Hill (Co/I/137-139).

Material: Only a few specimens were collected. Some are preserved as carbon films in fresh rock but most are merely iron stains with slight relief in badly leached material.

Discussion: Some doubt exists as to the individualities of the two orthograptid species *O. pageanus* and *O. whitfieldi* and their varieties, and in time these two may prove to be conspecific. In fact Ross & Berry (1963) have placed *O. whitfieldi* in the species *O. quadrimucronatus* which it and *O. pageanus* resemble. The main criterion for separating the two in the past has been their size, larger specimens being assigned to *O. pageanus* and the smaller to *O. whitfieldi*. Unfortunately this is not a hard and fast rule as some of the subspecies of *O. pageanus* may be quite small *(O. pageanus microcanthus)*. The form here described is smaller than any spined orthograptid and so is placed in the smaller species *whitfieldi*, though with some reservation as it is much broader for its length than usual in this species.

The main objection of Elles & Wood to this identification would be that the sicula does not have a long stiff virgella. However, this may not be of taxonomic importance, as J. Hall, the author of the species, describes it 'Sicular extremity

furnished with a little conspicuous virgella'. The idea of a long virgella appears to have been introduced by Lapworth (1876, 1877). As well, all the other varieties of both *O. whitfieldi* and *O. pageanus* have a long virgula approximately equal to the length of the rhabdosome, while the form here described shows only a very small one in only one specimen. Most of the specimens collected had a sharply truncated end giving the appearance of having been broken, but this is not likely as most of the specimens are identical in this respect, and if present a virgula would would probably be short and/or slender.

Orthograptus apiculatus (Elles & Wood) 1907

(Figs. 4d, e)

Diplograptus (Orthograptus) rugosus var. *apiculatus* Elles & Wood 1907, p. 245-6; Pl. 30, fig. 7a-d.
Orthograptus apiculatus Bulman 1945, p. 51-58; Pls. 5-6, fig. 1-7.
Diplograptus (Orthograptus) apiculatus Sherrard 1949, p. 73, text-figs. 21a, b, c; Pl. 2, fig. 72.

DIAGNOSIS: The rhabdosome is straight and 'the length may be as much as 4½ cm and particularly where it is less than this there is usually visible a conspicuous virgula' (Bulman 1945). It commences from a rather broad proximal end and rapidly widens to its maximum width. The thecae are sigmoidal proximally but become progressively straighter distally: they number 9-10 per cm in mature segments of the rhabdosome.

DESCRIPTION: The rhabdosome is straight and according to Bulman (1945) may reach a length of 4½ cm: the largest fragment collected here had a length of 3½ cm but was obviously incomplete. The shape of the rhabdosome is very characteristic in that the proximal end is already wide and the maximum width from here is attained rapidly, after which it is virtually parallel-sided. The width at the first thecae (Th 1^1, Th 1^2) ranges from 1·3 mm to 1·5 mm and the maximum value ranges from 2·6 mm to 3·5 mm, the ones with the narrower proximal end tending to be slightly narrower throughout. A median septum may be seen where the preservation is good, and in 9691 what is apparently a broad virgula may be seen extending for some way past the distal end. The most proximal end is aseptate but the actual point of origin of the septum is not clearly shown. In the British specimens (Elles & Wood 1907, Bulman 1945) it arises from between the 5th and 7th thecal pairs. The thecae number from 9 to 10 per cm in the distal portions of the material measured but are apparently slightly more frequent in the very early portions.

The thecae are particularly variable in this species and grade from a mild glyptograptid shape proximally to curved orthograptid distally. The first thecal pair grow alongside the sicula entirely covering it and are distinctive in having short mesially positioned spines. The following thecae are sigmoidal in form with the aperture of the preceding theca in a definite excavation. These thecae gradually lose this strong impression and the distal thecae, though still sigmoidal, tend to be only gently curved. The mature thecae have a length of around 2 mm with a range of 0·2 mm on either side. The width, however, is not as constant, the most common value being around 0·5 mm but ranging from 0·4 mm to 0·7 mm. The thecae overlap each other from half to two-thirds their length and have an average inclination of a little over 30° to the axis of the rhabdosome.

The sicula is entirely imbedded in the proximal thecae and its length could not be measured. However, its aperture is ornamented by a virgella opposite two apertural spines of short nature, which enables the width to be measured at 0·4 mm. The virgella points directly downwards but the other apertural spines are

deviated through a large angle. Only one apertural spine could be seen in the specimens collected, but this is probably due to bad preservation as Bulman shows this spine to be paired.

Material: The preservation of the specimens was always rather unsatisfactory, being in semi-relief but with the carbonaceous material frequently flaked away. Where the carbonaceous film is absent only an external impression is seen without the median septum or junction of the thecae.

Horizon and Localities: All the specimens came from the one locality, Co/I/137, at the base of the Mallongulli Formation.

Discussion: The best and most detailed description of this species is that of Bulman (1945), where from large amounts of isolated, transparent material and serial sections, he was able to measure many features not otherwise measurable, note the range of variations and map out the ontogeny from the early growth stages. Bulman's treatment is very complete and his work should be referred to as only a few points of further difference will be discussed here.

Bulman states that overall the rhabdosome is variable in length and breadth, but although the lengths of the fragments here studied did not approach his maximum the width reached was somewhat wider than his maximum (as quoted for flattened material, 3·5 mm to Bulman's 3·4 mm).

Elles & Wood (1907) state that the spines on the first theeal pair are entirely apertural and in fact grade into apertural denticles. Bulman places them in a slightly lower mesial position with a small distance to the apertural lip, while these specimens have them even further from the aperture.

The variation of the theeal shape is summarized well by Bulman (1945, p. 57): 'The appearance of the proximal end of the rhabdosome (to the fifth or sixth theeal pair—roughly corresponding to the aseptate portion of the rhabdosome) may be almost glyptograptid (Plate 6, fig. 3) or even amplexograptid (Pl. 6, fig. 6) according to the intensity of the sigmoidal curve of the thecae. In the more mature portion of the colony (e.g., around the tenth or twelfth theeal pair) the curvature of the ventral wall is much less and this general character it appears to retain to the distal extremity (e.g., Text-fig. 24a), where, too, the thecae are more rectangular in section.'

The thecae of the specimens described here appeared closer to Bulman's specimens than Elles & Wood's. Especially the change in theeal outline with rotation from profile to half-profile view is similar to Bulman's. The full-profile views of Elles & Wood (Fig. 166a-e) are only rarely seen in short portions of the rhabdosomes.

The sicula also has a number of variations (the virgella is shorter and more slender than both Elles & Wood (op. cit.) and Bulman (op. cit.) have figured); especially it never attains the proportions figured by Bulman as Fig. 29B. As well, on the specimens studied only one other apertural spine was noticed; this could have been real or apparent as the preservation was not good in this region. The spine is also somewhat more slender than Bulman's and the second could have been hidden by the superimposition of the first.

Genus **Glyptograptus** Lapworth 1873

Glyptograptus cf. **G. tenuissimus** Ross & Berry 1963

(Fig. 5a-d)

Diagnosis: The rhabdosome is straight, over 2½ cm in length and relatively narrow, usual maximum width 2·5 mm. It is somewhat fusiform in shape, taper-

ing for the proximal and distal thirds. Thecae short, stubby glyptograptid with small overlap, inclined at about 25° to the axis of the rhabdosome and number between 9 and 10 per cm in mature portions or slightly more proximally. First two thecae may carry short mesial spines.

DESCRIPTION: The rhabdosome is straight and slender and when complete has a fusiform outline. A common length is between 3 and 3½ cm though fragments have been found indicating a length substantially greater than this at times. The initial width varies between 0·7 mm and 0·9 mm but a width of 0·8 mm is more common. The rhabdosome gradually widens for about the first third of its length to a maximum of 2·5 mm though slimmer specimens 1·8 mm and broader specimens 3·0 mm have been found. After this point it is almost parallel-sided to the distal third during which it tapers, though less rapidly than through the initial third. The thecal count is between 9 and 10 per cm for mature portions of the rhabdosomes and up to 12 per cm in the proximal region.

The thecae are relatively stubby, gently sigmoidally curved and have a small overlap. The length is about 2 mm but owing to the bad preservation no exact value could be measured. The width is approximately one third of the length at 0·6 mm and overlap, where it can be established, appears to be about one third. The thecae are inclined at an angle of between 25° and 30°. The excavation is open and wide and takes up as much as one quarter of the width of the rhabdosome. The aperture which has a slight tendency to introversion is almost straight, with only a few showing an undulation. The initial two thecae depart from this pattern in that their curvature tends to be rather angular and sometimes this point of geniculation carries a spine (sometimes on only one theca, sometimes on neither).

The sicula was seen in only one specimen where it is curiously curved. It is a simple cone just over 1 mm in length and with a width of nearly 0·2 mm. It possesses, as a rule, a short stiff virgella. From the prosicula end a virgula can be seen to run the whole length of the rhabdosome and extend sometimes just past the distal end.

MATERIAL: Large numbers of this species were collected but usually poorly preserved in leached rock.

HORIZON AND LOCALITIES: The fossil is common through the whole thickness of the Mallongulli Formation. All the specimens here described came from the one locality, Co/I/139.

DISCUSSION: From the description it can be seen that there is a 'mean' type which is by far the most abundant and which is surrounded by less common, broader or thinner forms. The thinner forms have their thecae inclined at a lower angle than the abundant forms; the broader forms have thecae inclined at a slightly higher angle. This relative width of the rhabdosome, then, can be shown to be primarily a function of the angle of inclination of the thecae, but whether this inclination is primary or due to preservation cannot be established.

It is difficult to ascribe this form to any given species as it differs in some ways from all those whose descriptions are available to me. However, most of these similar species have similar ranges, showing their close evolutionary affinities, and it is felt unnecessary to establish a new species, preferring to envisage it as an Australian equivalent. Consequently, it has been placed into Ross & Berry's *G. tenuissimus*. It differs from *G. tenuissimus* in a number of points which are all a function of its being a coarser form. Because of its thicker components it is wider,

both initially and at a maximum, and the thecal count is slightly smaller than in the American specimens. The thecal excavation is not as deep as Ross & Berry state (1963, p. 142) but their Plate 11, fig. 6, would seem to indicate that they had overstated its depth. Ross & Berry apparently had no proximal end to their specimen (Pl. 11, fig. 6) and so the spines on the initial thecae of the Australian specimens could be present on theirs, although it has been shown that they are not neecessarily present even in the Australian specimens.

Sherrard (1954) has apparently identified this species as *G. teretiusculus*, which is not particularly satisfactory since that species is a far larger and generally different form. Sherrard's description (p. 98-99) is obviously a composite description which borrows heavily on specimens collected elsewhere than in this area as her measurements in no way agree with the material from here. Her figure of a specimen from the area (1954, Pl. 11, fig. 16) does not shed much light on the situation as the typical preservation does not photograph well.

Family Retiolitidae Lapworth 1873

Subfamily Archiretiolitinae Bulman 1955

Genus **Orthoretiolites** Whittington 1954

cf. **Orthoretiolites hami** Whittington 1954

(Figs. 5g, h)

Retiograptus geinitzianus Sherrard 1954, p. 99, Pl. 11, fig. 20.

Diagnosis: Only sicula and initial parts of the first three thecae ($th1^1$, $th1^2$ and $th2^1$) chitinized; the rest of the rhabdosome represented by a clathria of lists, and composed of only few thecae. Thecae of orthograptid pattern with an apertural spine number 10 to 12 per cm in mature portions of the rhabdosome. Sicula with a virgula and virgella and paired spines at aperture.

Description: The most complete specimens show the rhabdosome to be expanding gradually from a rounded proximal end for the first five or so thecae, after which it is parallel-sided. The initial width is 1·0 mm (across the aperture of the first two thecae) and the maximum reached is 1·6 mm, both values excluding apertural spines. The largest specimen studied had a length of 9½ mm, excluding protruding virgula. The number of thecae per cm varies between 10 and 12 in mature portions but towards the proximal extremity may rise to 15.

The cross section of the thecae cannot be seen from the specimens owing to the compression of burial, but the pattern of lists would suggest that they may have been rectangular. Overall the shape of the thecae can be favourably compared with the orthograptidae and on a finer scale most of the lists described by Whittington can be identified. The mature thecae reach a length of 1·7 mm and a width of 0·5 mm, but decrease progressively in size towards the proximal end. The angle of inclination of the thecae is constant along the stipe, at about 35°. The most distinctive feature of the thecae is their large, single apertural spine (the aperture is everted and this would compare with the apertural dentiele of an orthograptid theca). The spine is usually stout, being of an equivalent thickness to the other lists of the rhabdosome and may reach a length of just over 1 mm, though half this is more common. The spines are also stiff in appearance but as a rule show some degree of downward curvature.

The sicula is large, 2 mm excluding virgella, and of gently curved, conical shape. It has a stout virgella and in specimen MF/27 (Sherrard number) may have paired apertural spines. The sicula is never well preserved and, though

appearing entirely chitinized, the chitin must have been very thin. The virgula can be seen to run the full length of the rhabdosome but is thin and not visible for its entirety. It is also sometimes parted from its supporting lists and tends to sag and become flexed.

MATERIAL: Owing to the absence of periderm the form is difficult to detect and this may account for the small numbers found. Only a few fragmentary specimens are in the collection of Mrs K. Sherrard who very kindly lent them to me.

HORIZON AND LOCALITIES: The specimens collected by the author came from locality Co/I/139, in the basal portion of the Mallongulli Formation, but the specimens of Mrs Sherrard came from a locality probably higher than this. Both horizons are probably of the same age.

DISCUSSION: Unfortunately not much work has been done on Ordovician retiolitidae and the work that has been done has been done on well-preserved isolated specimens. The criteria which have been used also require good preservation of the most proximal region. The specimens available for study have unfortunately been unsatisfactory to some degree in this respect, and the identification is tentative.

As can be seen from the synonomy the author regards Sherrard's identification as *Retiograptus geinitzianus* as incorrect. Sherrard's description does not fit her specimens from this area and is obviously a composite of those specimens and others from Tomingly, N.S.W., with more emphasis on the foreign ones: for instance, her description of two apertural spines per theca, etc., which is not borne out by her plate (Pl. 11, fig. 20).

The graptolite compares well in overall dimensions to *Retiograptus pulcherimus* as described by Berry (1966, p. 445), differing only in the size of the sicula. However, neither Berry nor the authors of the species (Keble & Harris 1934) give sufficient description of this part of the rhabdosome for positive identification. Though only two whole specimens have been found at Cliefden Caves, no fragments any larger have been found, indicating that this is probably the mature size for the species, making it much shorter than the 12 cm length of *R. pulcherimus*. Though *R. pulcherimus* has only short spines distally (Keble & Harris 1934, Fig. 6 and Pl. 22, fig. 1; Berry 1966, Pl. 50, fig. 8) they become more common and prominent proximally, and close to the sicula are very similar to those of the two specimens here described. Unfortunately it is hard to decide the true affinities of *R. pulcherimus* from the published descriptions and figures. The figure of Keble & Harris (1934, Pl. 22, fig. 1 and Fig. 6) appear to have the same components as *O. hami*, though with slightly different proportions, but the photo of the holotype (Berry 1966. Pl. 50, fig. 8) shows a more complicated assemblage of lists. This is probably due to compression in a half-profile view but until a three-dimensional model is attempted from this and other material its affinities must remain in doubt.

So far there have been only two subspecies of *O. hami* erected, the original *O. hami* of Whittington and *O. hami robustus* of Skevington (1960). The graptolite here described differs from both of these to some degree but owing to the poor preservation no attempt is made to place it into a subspecies (4 thecae in Whittington's and 6 to 7 in Skevington's, compared to at least 12 here). A second difference is the much larger sicula in these specimens. Whittington described the sicula as 0·9 mm in length and reaching only to the third thecal pair (substantiated by Skevington) while here the sicula reaches a length of over 2 mm and reaches well into the fourth thecal pair. Lastly there are also some minor differences in

proportions of the various components but no attempt has been made to evaluate the significance of these.

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References

Adamson, C. L., & Trueman, N. A., 1962. Geology of the Cranky Rock and the Needles Proposed Dam Storage Areas, Canowindra. *Geol. Surv. N.S.W. Rept. No. 11.*

Berry, W. B. N., 1966. *Climacograptus hastatus* T. S. Hall—Its Lectotype and some Local Populations. *J. Paleont.* 40: 162-176.

————, 1966. A discussion of some Victorian Ordovician graptolites. *Proc. Roy. Soc. Vict.* 79: 415-448.

Booker, F., 1950. The Angullong Deep Lead. *Geol. Surv. N.S.W. Reports* for 1939-45 (1950): 24-26.

Bulman, O. M. B., 1933. On the Graptolites Prepared by Holm Pt. I. *Arkiv Zool.* Bd. 24A, No. 8, p. 1-46, Pl. 1-9, fig. 1-18.

————, 1944. The Caradoc Graptolites from Limestones in Laggan Burn, Ayrshire. *Palaeont. Soc. London*, p. 1-78, Pl. 1-10, fig. 1-40.

————, 1955. Graptolithina. *Treatise on Invertebrate Paleontology*, Pt. V. Geol. Soc. Am. & Univ. of Kansas.

Decker, C. E., 1935. Graptolites of the Sylvan Shale of Arkansas. *J. Paleont.* 9: 697-708.

————, 1952, Stratigraphic significance of Graptolites of the Athens Shale. *Am. Ass. petrol. Geol., Bull.* 36: 1-145.

Elles, G. L., & Wood, E. M. R., 1901-1918. Monograph of British Graptolites. *Paleont. Soc. London* clxxi + 539 p., 52 Pl., 359 fig.

Hall, J., 1859. *Natural History of New York, Part 6. Palaeontology. Vol. 3.* 532 p., figs. Geol. Surv. N.Y., Albany, U.S.A.

Hall, T. S., 1900. On a Collection of Graptolites from Mandurama. *Geol. Surv. N.S.W., Rec.* No. 7: 16-18.

————, 1905. Victorian Graptolites Pt. III; From Near Mount Wellington. *Proc. Roy. Soc. Vict.* 18: 20-24.

————, 1906. Reports on Graptolites. *Rec. Geol. Surv. Vict.* I, Pt. 4: 266-278.

Harris, W. J., 1926. Victorian Graptolites. *Proc. Roy. Soc. Vict.* 38: 56-61.

Harris, W. J., & Thomas, D. E., 1938. A revised Classification and Correlation of the Ordovician Graptolite Beds of Victoria. *Mining geol. J.* Vol. I, No. 3: 62-72.

————, ————, 1955. Victorian Graptolites Pt. XIII; Graptolites from the Wellington River, Pt. 1. *Ibid.* 5: 3-13.

Hopkinson, J., 1870. On the Structure and Affinities of the Genus *Dicranograptus. Geol. Mag.* 7: 353-59.

————, 1871. On *Dicellograptus*, A New Genus of Graptolites. *Ibid.* 8: 20-26.

Jaaanusson, V., & Skoglund, R., 1963. Graptoloids from the Viruan (Ordovician) Dalby and Skagen Limestones of Vastergotland. *Geol. Foren. Forhandl.* 85: 341-357.

Keble, R. A., & Harris, W. J., 1925. Graptolites from Mount Easton. *Rec. Geol. Surv. Vict.* IV, Pt. 4: 507-516.

————, ————, 1934. Graptolites of Victoria. New Species and Additional Records. *Mem. nat. Mus., Melbourne* 8: 166-183.

Lapworth, C., 1876. A Catalogue of West Scottish Fossils; in Armstrong, J., Young, J., and Robertson, D., *The Silurian System in the South of Scotland.* Brit. Acad. Sci., London.

————, 1877. The Graptolites of County Down. *Proc. Belfast Naturalists' Field Club*, Appendix, 1876-77: 125-44.

Moors, H. T., 1966. Unpublished M.Sc. Thesis, Univ. of Sydney.

Öpik, A. A., 1952. Shelly Ordovician Strata at the Belubula River. *Australian Bur. Min. Resour., Geol., Geophys. Unpublished Rept.* No. 22.

Ross, R. J., & Berry, W. B. N., 1963. Ordovician Graptolites of the Basin Ranges in California, Nevada, Utah and Idaho. *U.S. Geol. Surv. Bull.* 1134.

Ruedemann, R., 1947. Graptolites of North America. *Geol. Soc. Am. Mem.* 19: 1-652, Pl. 1-92.

Sherrard, K. M., 1949. Graptolites from Tallong and the Shoalhaven Gorge, N.S.W. *Proc. Linn. Soc. N.S.W.* 74: 62-82.

————, 1954. The assemblages of Graptolites in N.S.W. *J. Proc. roy. Soc. N.S.W.* 87: 73-101.

————, 1962. Further Notes on the Assemblages of Graptolites in N.S.W. *Ibid.* 95: 167-178.

————, & Keble, R. A., 1937. The Occurrence of Graptolites near Yass. *Proc. Linn. Soc. N.S.W.* 60: 303-314.

Skevington, D., 1960. A New Variety of *Orthoretiolites hami* Whittington. *Paleontology* 2: 226-235.

Smith, R. E., 1966. The Geology of Mandurama-Panuara. *J. Proc. roy. Soc. N.S.W.* 98: 239-262.

Stevens, N. C., 1952. Ordovician Stratigraphy of Cliefden Caves, near Mandurama, N.S.W. *Proc. Linn. Soc. N.S.W.* 77: 114-120.

————, 1954. Unpublished Ph.D. Thesis, Univ. of Sydney.

Thomas, D. E., 1960. The Zonal Distribution of Australian Graptolites. *J. Proc. roy. Soc. N.S.W.* 94: 1-58.

Trickett, O., 1908. Report on Cliefden Caves, Warm Springs and Fossil Hill, Belubula. *Geol. Surv. N.S.W. Ann. Rept.*, p. 172.

Whittington, H. B., 1954. A New Ordovician Graptolite from Oklahoma. *J. Paleont.* 28: 613-21.

————, 1955. Additional New Ordovician Graptolite and a Chitinozoan from Oklahoma. *Ibid.* 29: 837-851.

Explanation of Figs. 1-5

The drawings were made by inking in the details on photographs of the graptolites at a magnification of 10. These were then compiled into Figs. and reduced by half to give a final magnification of approximately five, except Figs. 1a (i)-(ii) and Fig. 2f.

FIG. 1—a-d. *Leptograptus eastoneusis* Keble & Harris. a. (i), (ii). Diagramatic representations of the variation near the sicular end. Approx. by 2. b. No. 9633 (i). Proximal end showing slender sicular and initial thecae; (ii) distal fragment showing thecal variation. c. No. 9632. Proximal end. d. No. 9628. Proximal end showing long narrow tapering sicula typical of the species. e-g. *Dicranograptus* cf. *D. kirki* Ruedemann. e. No. 9637. Proximal end showing virgella and thecae of the biserial portion. Thecae 1^1 and 1^2 carry short mesial spines. f. No. 9638. Large distorted specimen showing torsion of stipes and shape of uniserial branch thecae, one of which carries a mesial spine. g. No. 9639. Typical specimen showing thecae of biserial portion.

FIG. 2—a-c. *Dicellograptus minutus* sp. nov. a. No. 9648. Broken specimen showing axil and shape of thecae. b. No. 9647. Badly preserved specimen showing the relatively large spines on the first thecae. c. No. 9646. Badly preserved but shows spines on first and second thecae, apertural and mesial respectively. d-g. *Dicellograptus elegans* Carruthers. d. No. 9649. Typical specimen (Sherrard 1953, Pl. 10, fig. 5) showing different preservation of the stipes. 'Right thecae. e. No. 9650. Typical poorly preserved specimen showing marked shape. f. Sherrard's specimen (Sherrard 1953, Pl. 10, fig. 5) showing different preservation of the stipes. 'Right hand' showing true shape, 'left hand' showing Sherrard's interpretation. g. No. 9653. Large specimen showing typical spines on first thecae, slowly tapering sicula, and general shape of thecae along the stipe.

FIG. 3—a-c. *Climacograptus tubuliferus* Lapworth. a. No. 9670. Typical large specimen showing the broad membrane surrounding the virgula within the polypary, extending past the distal end and surrounding most of the virgella. Note the sharp geniculation of some of the thecae which could have been responsible for the identification of *Amplexograptus* from the area. b, c. (9672 and 9673). Typical smaller forms with the central membrane developed best in 9672 where it covers most of the virgella and at the distal end rapidly broadens. d-e. *Climacograptus bicornis* (Hall). d, e. Two specimens with spines diagramatically exaggerated in size. f. *Climacograptus* cf. *C. supernus* Elles and Wood. f. No. 9657. Only specimen, with spines diagramatically exaggerated in size. g-i. *Climacograptus fusiformis* sp. nov. g. No. 9664, holotype. Large individual showing typical half-profile view distally but biprofile view proximally. Broad virgula may be seen within the rhabdosome. Slight tapering distally noticeable, but specimen incomplete. h. No. 9666. Narrower, slightly bent specimen, showing the path of the virgula within the rhabdosome. i. Small specimen showing stout, curved virgella.

FIG. 4—a. *Climacograptus tridentatus* Lapworth. a. No. 9656. Only specimen showing virgula inside rhabdosome and three large, incomplete, basal spines with membrane. b-c. *Orthograptus truncatus* aff. *pauperatus* Elles & Wood. b. No. 9687. Typical, though badly preserved specimen. c. No. 9680. Slender form with thecae inclined at a lower angle than usual. Virgula visible within rhabdosome. Theca 1^2 has a mesial spine, sicula carries a short virgella. d-e. *Orthograptus apiculatus* (Elles & Wood). d. No. 9691. Typical specimen showing the path of the median septum. e. A more slender form poorly preserved. f-i. *Orthograptus calcaratus clavensis* sp. nov. f. No. 9683, holotype. Slightly bent, showing parth of virgula, spines on both initial thecae and long curved virgella. g. No. 9685. Incomplete proximal end. h. No. 9686. Incomplete proximal end. i. No. 9687. Incomplete distal end to indicate the size reached. Shows the path of the virgula.

FIG. 5—a-d. *Glyptograptus* cf. *G. tenuissimus* Ross & Berry. a. Large specimen showing inclined, curved sicula, no basal spines. b. Typical broad form. c. Typical narrow form showing virgula within distal end and extending past it. One basal spine prominent. d. Typical specimen with the virgula seen at times within the rhabdosome and extending past it. Both of the basal thecae bear spines and the sicula has a stout virgella. e-f. *Diplograptus ingens wellingtonensis* Harris & Thomas. e. No. 9659. Badly preserved specimen but showing thecal shapes and variation along stipe. Path of the virgula can be seen within the rhabdosome f. No. 9659. Slightly larger specimen showing slight prolongation of virgula. g-h. *Orthoretiolites* cf. *O. hami* Whittington. g. Figured specimen of Sherrard 1954, Pl. 11, fig. 20, showing long curved sicula, stout, drooping apertural spines and the general pattern of the lists. h. No. Mf/25 (Sherrard number). Slightly more jumbled specimen. A broader specimen with longer apertural spines. Thecae appear to be inclined at a slightly higher angle than those of g. i-j. *Orthograptus whitfieldi* (Hall). i. No. 9661. Typical specimen showing median septum slightly displaced by torsion of the rhabdosome. The apertural spines are not large. j. No. 9660. Broad specimen with median septum and showing thecal apertures drawn out into denticles, most of which are large enough to be called spines.

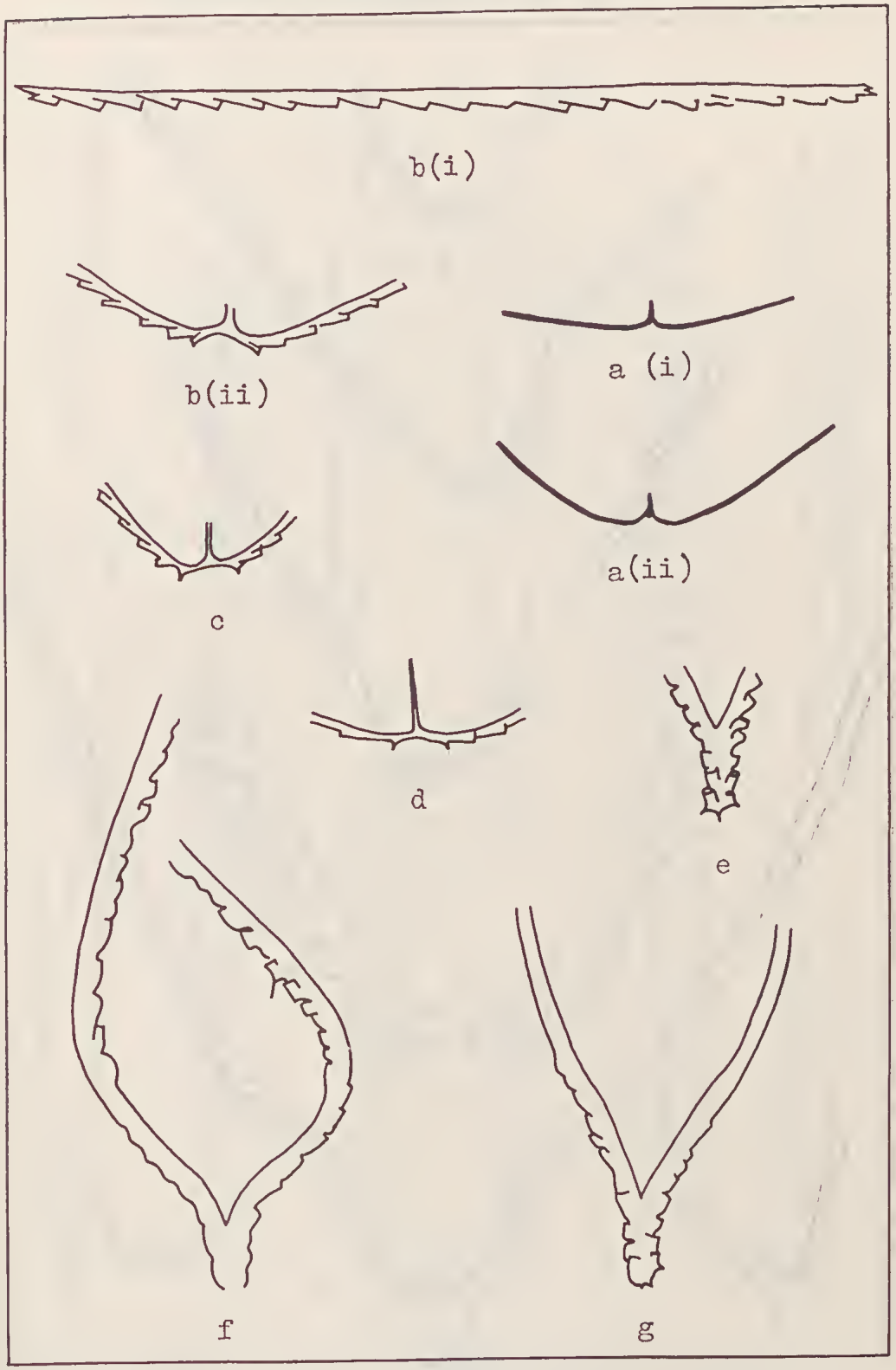

FIG. 1

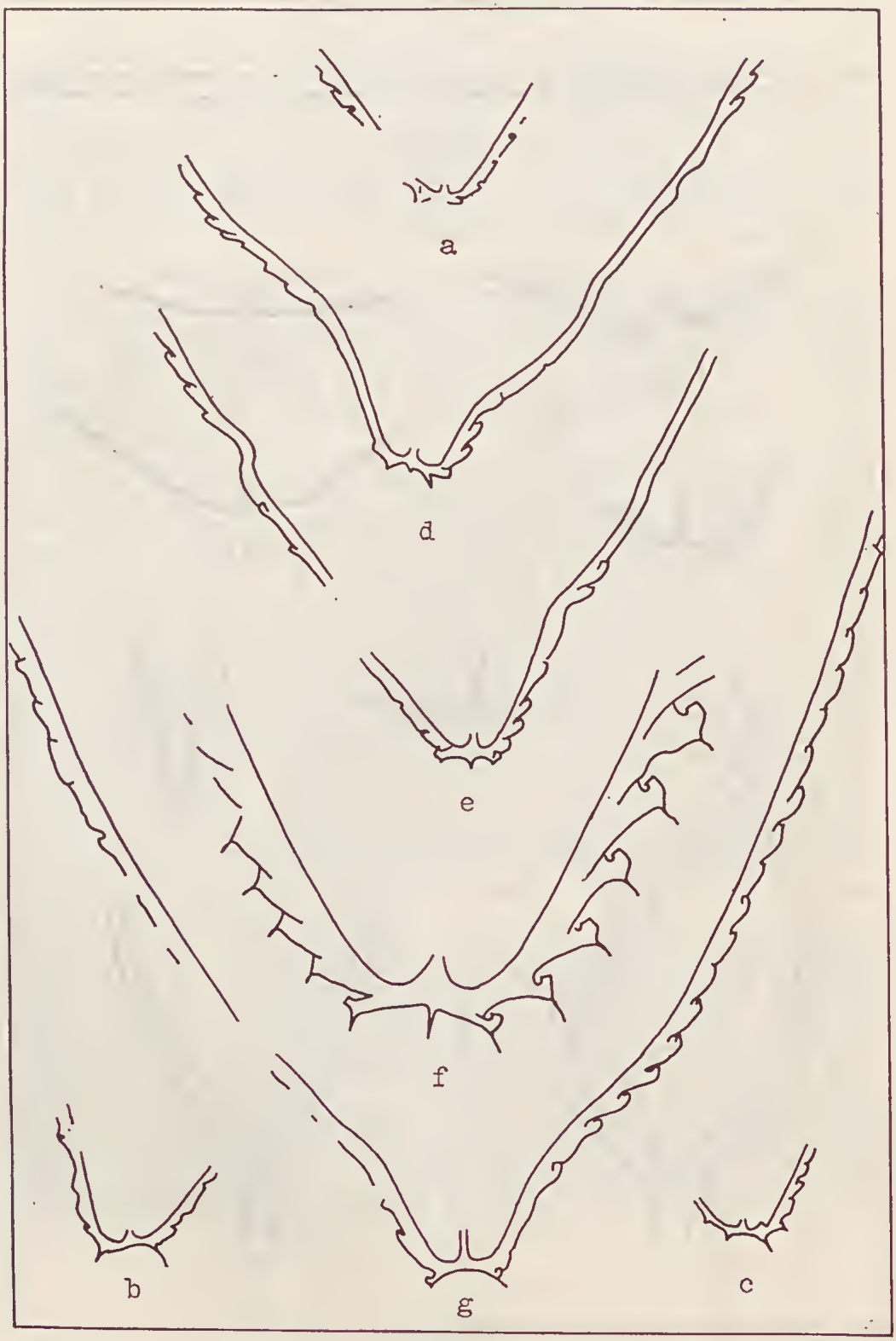

FIG. 2

FIG. 3

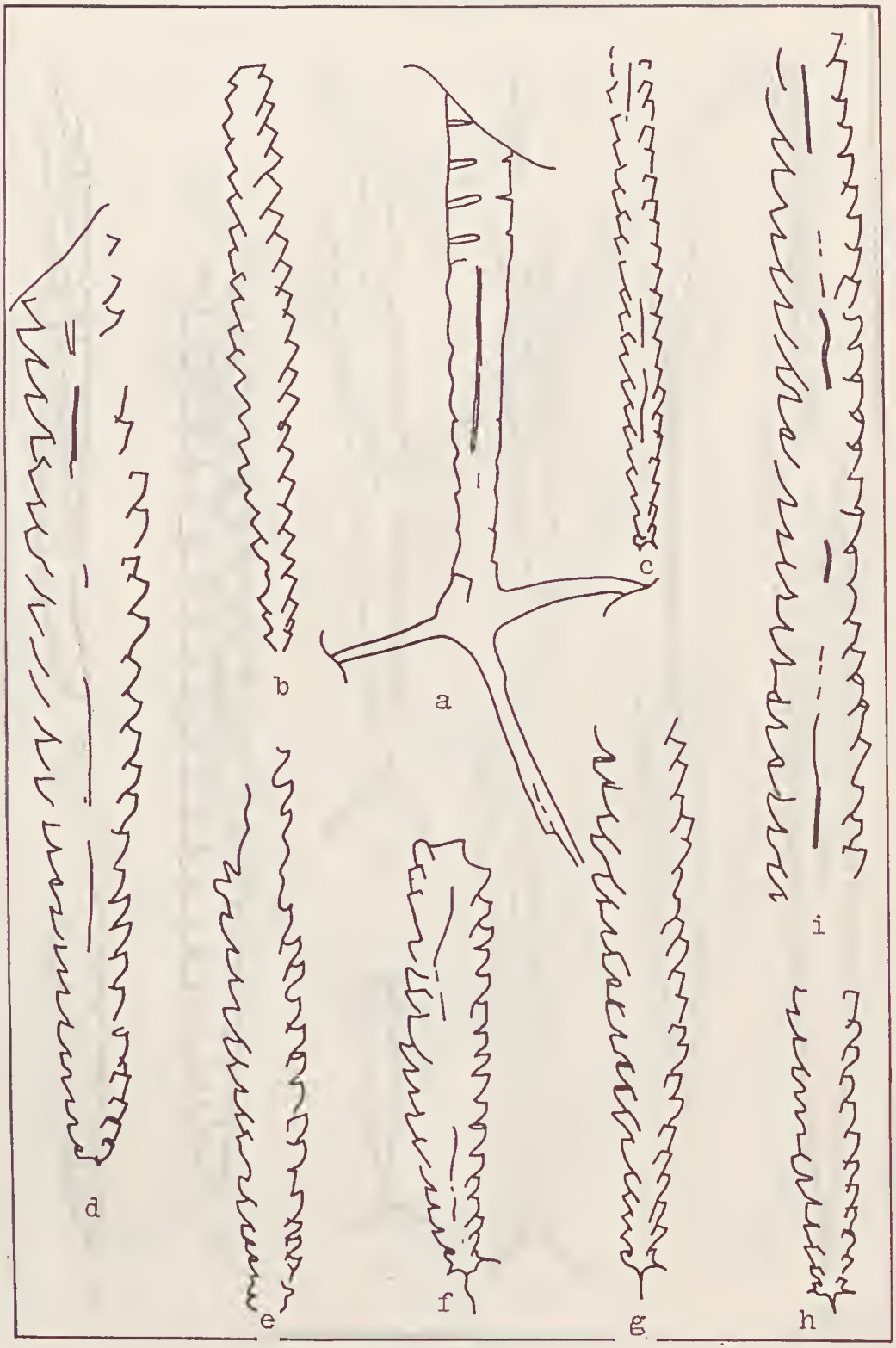

FIG. 4

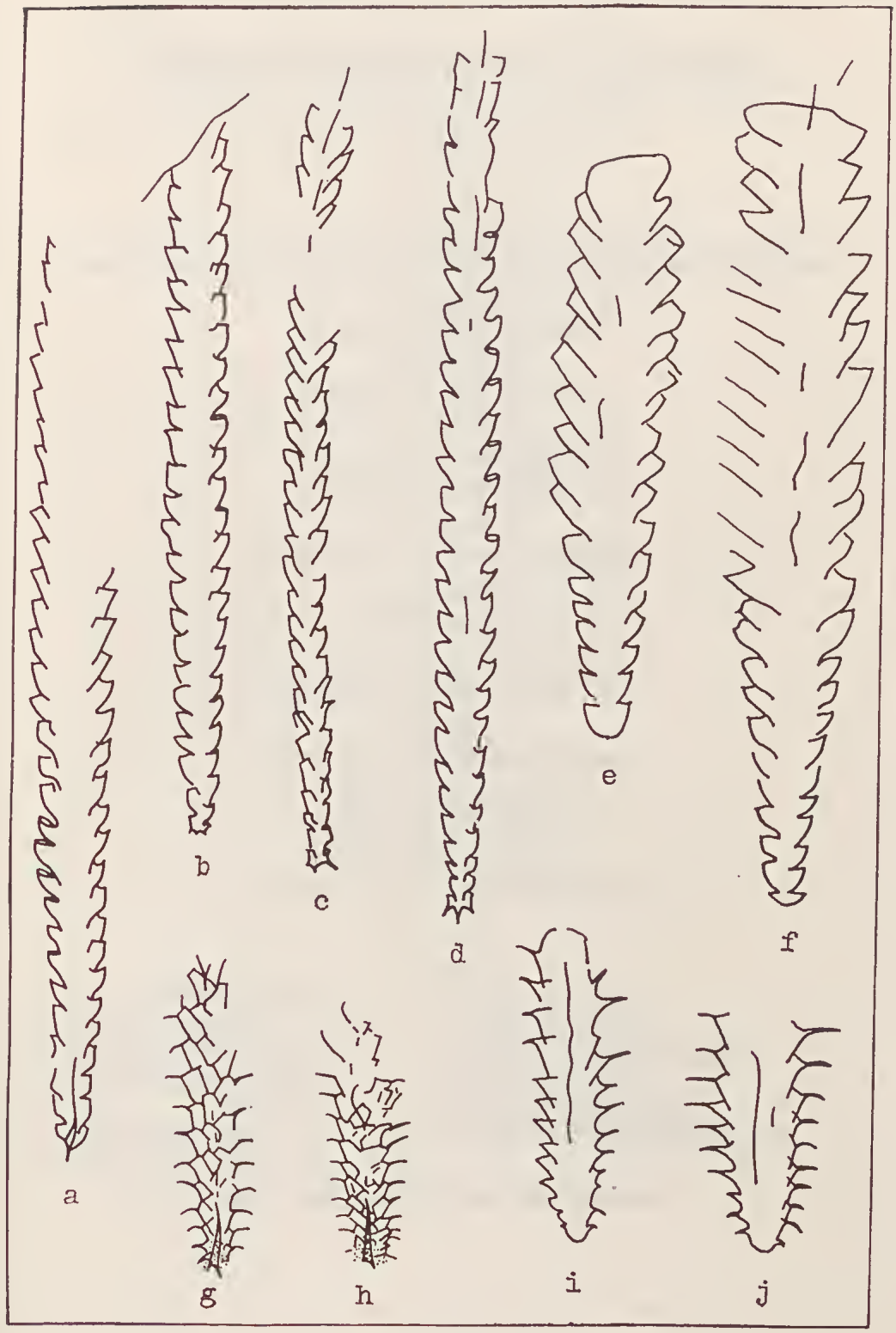

FIG. 5